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The Atmospheric Transport Model for Toxic Substances (ATM-TOX)

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ABSTRACT

An updated version of the Atmospheric Transport Model includes a wind profile, afternoon and nocturnal mixing heights, and first-order degradation of the airborne species. The previous version included the effect of aerodynamic roughness on dispersion constants, terminal and deposition velocities, plume tilting for heavy particles, and an episodic calculation of exposure maxima. The model calculates atmospheric concentration for both wetfall and dryfall. Sample input and output demonstrate the use of the model.

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1. THE ATMOSPHERIC TRANSPORT SUBMODEL

1.1 INTRODUCTION

The Atmospheric Transport Model (ATM) is a computer program for predicting the concentration and deposition on the earth's surface of airborne pollutants from point sources (such as smokestacks), line sources (such as rows of smelters), and area sources (such as landfills). ATM can be used by itself or as part of a larger, more comprehensive model to calculate the airborne concentrations and cumulative depositions at up to 40 gage sites of up to 20 pollutants downwind from a maximum of 10 point sources, 10 line sources, and 10 area sources. The program is written in FORTRAN IV and requires a central processing unit with at least 700K of user memory and the normal peripherals. The program was developed on an IBM system, and some coding conventions (such as data-block identifiers) reflect the vernacular of that system, but they are readily changed for use of the program on other systems. Data characterizing the pollutants, pollution sources, terrain surrounding the sources, and meteorology must be supplied by the user. Several parametric choices must also be specified by the user to accurately reflect the circumstances being modeled and to provide control over the various functions of the program. Evaluations of and validation efforts for this model are reported elsewhere (Culkowski and Patterson, 1976; Raridon and Murphy, 1982).

ATM was originally developed at ORNL by Mills and Reeves (1973) under the sponsorship of the National Science Foundation—Research Applied to National Needs Program (NSF–RANN). The ATM provides a means of calculating the ground-level air concentrations of trace contaminants from various sources and the deposition of those contaminants on a watershed. The subsequent movement of the contaminants through the watershed by hydrologic processes can then be traced with other models, such as WHTM (Patterson et al., 1974).

The scope of ATM was expanded and several new capabilities were added by Culkowski and Patterson (1976). These additional capabilities included Hosker's (1973) formulation of the sigma dispersion constants to include (1) the effect of aerodynamic roughness length, (2) a tilting of the plume for heavy particles, (3) evaluation of episodic exposure maxima for conditions of adverse meteorology, and (4) constraints on the allowed maximum values of the dispersion parameters.

Culkowski and Patterson (1976) streamlined and modularized the program to make it easier to follow the flow of the calculations. They reorganized the input and put the table of Pasquill-Gifford (1962) dispersion parameters in a block-data subprogram. Their addition of the Hosker (1973) formulation of the Briggs (1973) and Smith (1973) dispersion parameters extended the applicable range of ATM to 50 km without sacrificing accuracy.

The current report integrates the material presented by Culkowski and Patterson with enhancements made to ATM to produce a state-of-the-art air quality model. These features include using afternoon and nocturnal mixing heights to allow for plume trapping, providing an exponential wind profile correction for elevated sources, allowing deposition velocities less than 0.01 m/s, using the Briggs dispersion parameters without the Smith roughness correction, and allowing first-order species degradation as a function of time.

The model is not drastically different from the previous versions and is still a standard, straight-line, Gaussian-plume model. It may best be described as a mathematical distillation of the relevant parts of Meteorology and Atomic Energy (Slade, 1968), a standard reference in the field of air pollution. Although it reflects the latest accepted thinking for mesoscale (100 m to 50 km) models, it is still based on restrictive assumptions, such as the presence of a straight-line wind field.

This improved version of ATM has been integrated into a comprehensive transport model for toxic materials called the Unified Transport Model (UTM)(Patterson et al., 1984) and has been applied independently to a variety of studies. These include estimation of ground-level air concentrations of cadmium near a smelter (Rupp et al., 1978), estimation of air concentrations and depositions of trace elements on a watershed caused by fly ash from a nearby coal-fired power plant (Lindberg et al., 1976), modeling of the transport of toxic metals in the vicinity of a lead smelter (Munro et al., 1976), estimation of population exposures associated with future power plant sitings (Murphy et al., 1978; Davis et al., 1978), and air quality studies associated with environmental impact statements (Stinton et al., 1978).

The following sections of this report explain the basic concepts employed by the analysis, the calculations and operations of the computer program, and the procedures for using the program. A listing of the program, the JCL needed to run it, sample input, and examples of output are provided in Appendixes.

2. BASIC CONCEPTS AND CALCULATIONS

2.1 GAUSSIAN PLUMES

ATM is an application of the Gaussian-plume model, which has been well described in preceding publications e.g., Gifford (Slade, 1968). With this model, for each point source, an image source at an equal distance below the surface of the earth has been postulated to make the flux of matter crossing the surface zero. This practice has been described by Mills and Reeves (1973) and is well accepted in atmospheric-pollution studies. Material in the plume is removed by wet and dry deposition processes. The dryfall mechanism employs the concept of a deposition velocity in which the rate of transfer of material from the plume to the landscape is proportional to the atmospheric concentration in the layer adjacent to the ground surface. The very successful techniques for predicting plume fallout that have evolved over the years start with an analogy to the classical equation for the conduction of heat in a solid. In this analogy, the concentration of matter suspended in a turbulent fluid may be written as

$$\frac{dq}{dt} = \frac{\partial}{\partial x}\left(K_x \frac{\partial q}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial q}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial q}{\partial z}\right) , \qquad (1)$$

where K_x, K_y, and K_z are eddy diffusivities in the respective directions, q is the concentration of material per unit volume, and t is time. In the case of a smoke plume from a point source, x is considered to be the distance the plume travels downwind, y the horizontal distance normal to the plume's centerline, and z the vertical distance normal to the plume's centerline.

For smoke plumes, K_x is usually small in comparison with the wind speed, and here it is assumed to be zero, eliminating the first term on the right in Eq. (1). K_y, K_z, and wind speed [implicit in the left term in Eq. (1)] vary with height and time. Although a myriad of solutions have appeared in the literature, the most often used is the "Gaussian plume model"

$$q(x, y, z) = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left[-\left(\frac{y^2}{2\sigma_y^2} + \frac{z^2}{2\sigma_z^2}\right)\right] , \qquad (2)$$

where,

q = concentration of pollutant (g/m^3),
Q = the release rate of a pollutant from a point source (gm/sec),

u = the wind speed (m/sec) and

σ_y, σ_z = diffusion coefficients in the y and z directions, respectively.

It is of fundamental importance in extending, using, or understanding any Gaussian-plume model, to realize that Eq. (2) is not an exact solution and its application is very restricted. The σ_y, σ_z, and values for u chosen are empirically determined, largely from observations at ground level. Inferences of plume concentrations at any place but the surface [from Eq. (2)] and the published values for σ are certain to introduce errors into the calculations.

2.2 WIND ROSES

Atmospheric dispersion and deposition of suspended material is largely determined by the direction and strength of the wind. "Wind roses" are statistical descriptions of wind behavior. Here they are used to show with vectors the frequency (e.g., as a fraction of a year or month) with which the wind blows in each direction, at each speed, and with each stability class. (Stability class is a meteorologic classification of the atmospheric properties within the planetary boundary layer as they relate to the dispersion of airborne material.) The stability class can be defined in terms of wind speed and amount of sunlight reaching the earth's surface. Classes 1 to 3 (or A to C) represent daytime conditions, with 1 (or A) being the lowest wind speeds. Classes 5 through 7 (E through G) represent nighttime conditions with 7 (G) being the lowest wind speeds. Class 4 (D) can occur during either day or night. The stabilty wind rose is built into the model as a frequency table. Sixteen wind directions are specified, with direction number 1 indicating wind from the north. Wind directions then progress clockwise around the rose in 22.5-degree increments. Thus, direction 16 indicates wind from the north-northwest. Correspondingly, the wind-speed classes have been divided into six categories that proceed from roughly 1 m/sec through 14 m/sec. There is a separate wind rose for each stability class. The six stability classes correspond to the conventional Pasquill-Gifford (Hilsmeier and Gifford, 1962) classification scheme proceeding from stability class A, called 1 in the program, through stability class F, called 6 in the program. The Pasquill-Gifford dispersion parameters are illustrated in Figs. 1 and 2. They were intended to be applied on scales less than 10 km. The Hosker formulation of the Briggs-Smith dispersion parameters (Hosker, 1973) is illustrated in Fig. 3. It is intended for use on cases up to 50 km and is included here for reference. Each of these dispersion parameters must be less than the mixing height of the planetary boundary layer. For each wind-speed class, a mixing depth has been incorporated in the program for that purpose.

2.3 SOURCES

In addition to point sources, the model includes line and area sources in which the origins of airborne pollution are modeled as idealized geometries. Line sources are broken into line segments, each of which fits completely within one of the 22.5-degree wind-direction sectors. The segments within each sector are further subdivided into nine equal pieces. Each piece is then modeled as a point source with the appropriate source strength for the whole piece.

For simplicity and economy, area sources are treated as roughly square or circular shapes mapped onto appropriate planar areas to take advantage of the radial nature of stability wind roses. Elongated areas may be broken up into two or more nearly circular area sources with the same source strength per unit area as the original area source. To preserve the roughly circular character of the area sources and leave the distance to the centroid approximately the same, the radial value of R of the centroid of an area source is set at the average distance of that area source from the receptor (Fig. 4a). Thus,

$$R = \frac{R_1 + R_2}{2} \tag{3}$$

where R_l and R_2 are parameters of the transformed polar area. Further, this transformed area must be approximately "rectangular", and its arc length in the θ direction must be approximately the same as its depth in the radial direction:

$$R_2 - R_1 = \frac{(R_1 + R_2)\Delta\theta}{2} \ . \tag{4}$$

The area of the actual source and that of the transformed source must be the same, thus

$$A = \frac{\Delta\theta}{2} \ (R_2^2 - R_1^2) \quad , \tag{5}$$

from which

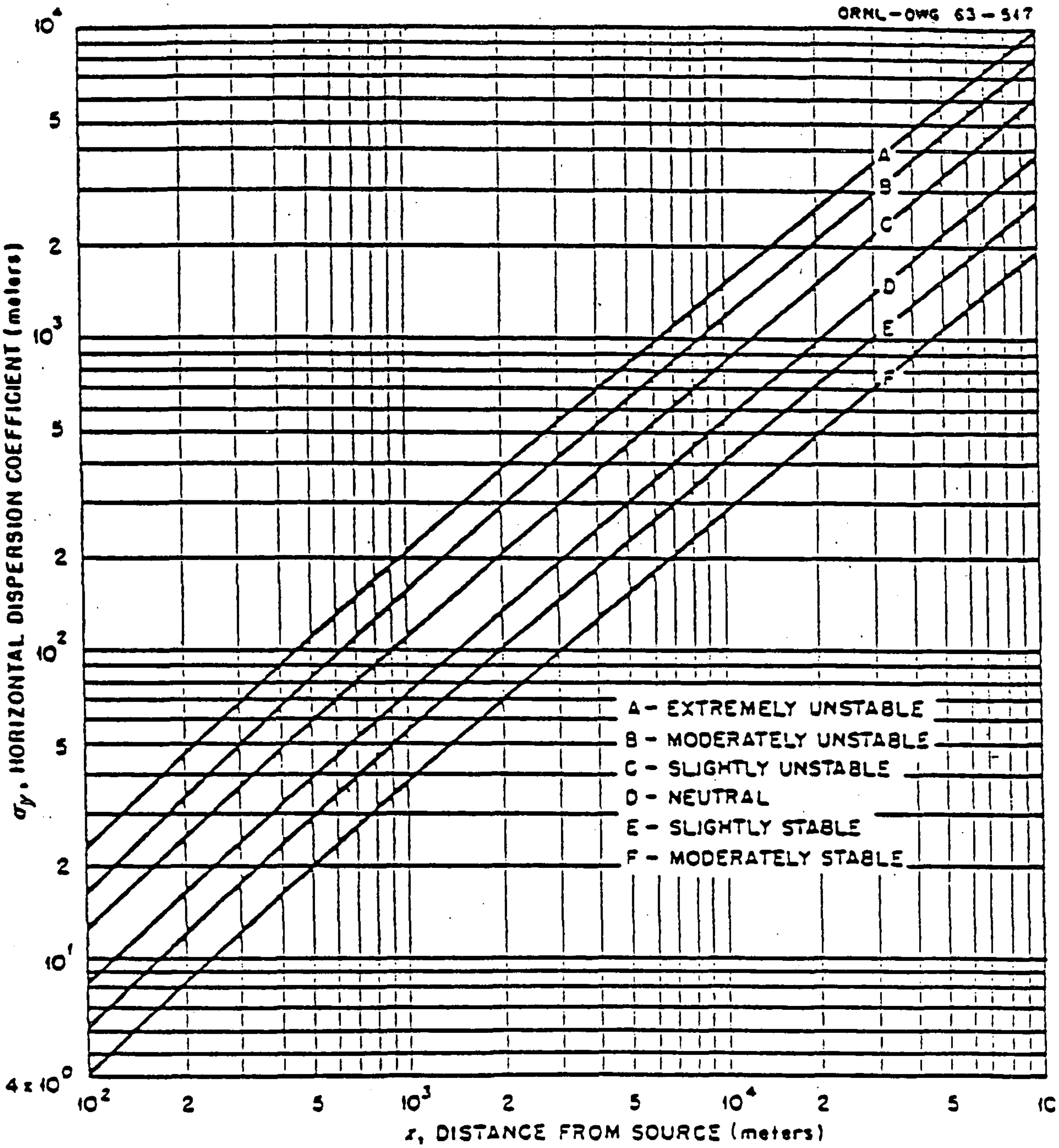

Fig. 1. Pasquill-Gifford horizontal dispersion coefficients versus distance.

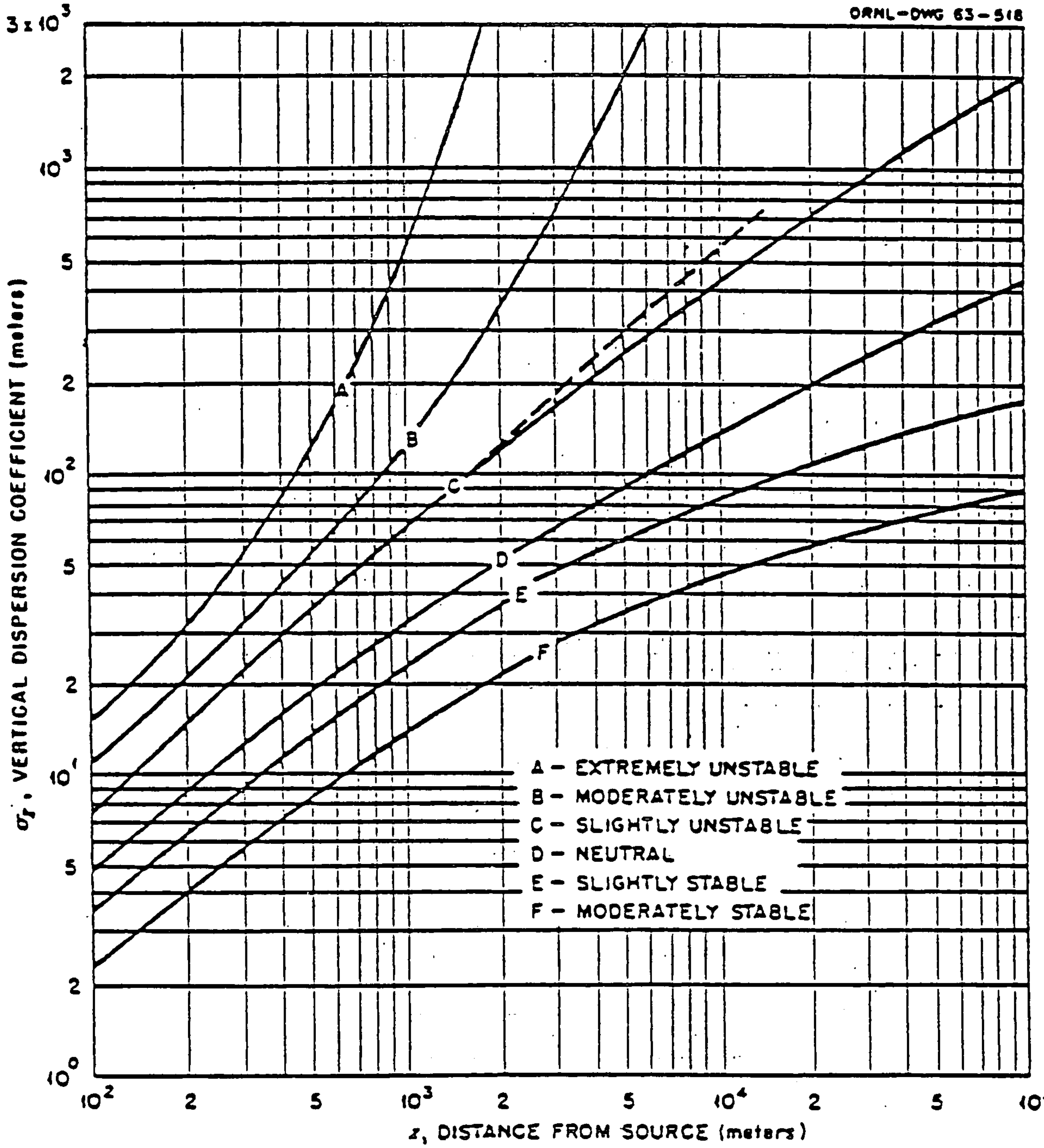

Fig. 2. Pasquill-Gifford vertical dispersion coefficients versus distance.

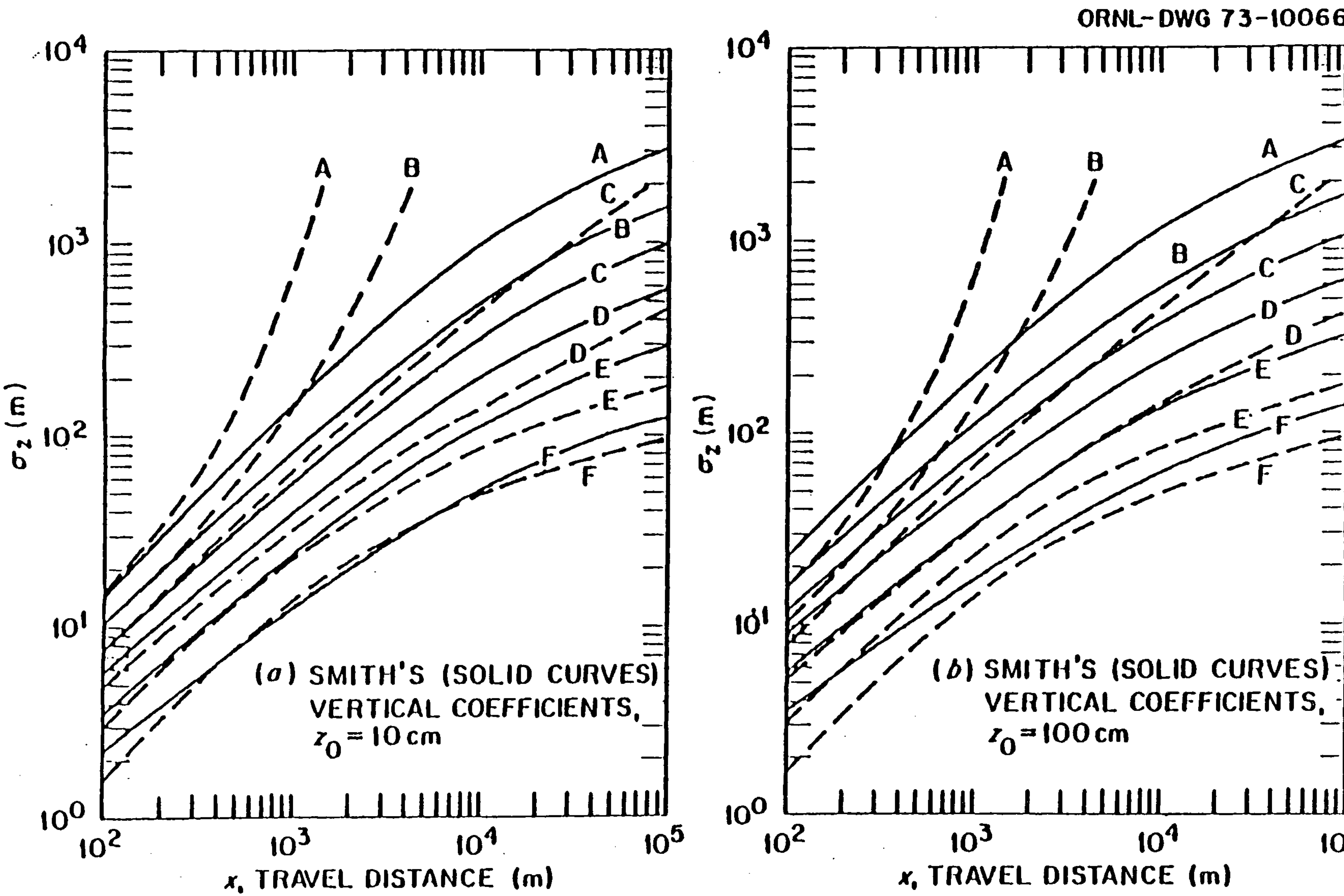

Fig. 3. Smith's σ_z (x) compared to Pasquill-Gifford σ_z (x) for all stability categories and two roughness lengths.

$$\Delta\theta = \frac{\sqrt{A}}{R} , \tag{6}$$

$$R_1 = R - \frac{\sqrt{A}}{2} ,$$

$$R_2 = R + \frac{\sqrt{A}}{2} ,$$

The conditions given above cannot be satisfied if the angle $\Delta\theta$ is larger than two radians because its radial dimension would have to be larger than the radius out to the centroid. In that case (Fig. 4b) the transformed area must be a sector of a circle with the dimensions

$$R_1 = 0 , \tag{7}$$

$$R_2 = 2R ,$$

$$A = \frac{R_2^2 \ \Delta\theta}{2} ,$$

which yields

$$\Delta\theta = \frac{A}{2R^2} . \tag{8}$$

Finally, if the value of $\Delta\theta$ calculated from the above equations is larger than 2π, the transformed area is considered a circle of radius

$$R_2 = \sqrt{\frac{A}{\pi}} \tag{9}$$

centered about the area source centroid as shown in Fig. 4c.

To maintain the generality of the program, the coordinate system for locating point, area, and line sources (as well as the receptor gages at which air concentrations and depositions are calculated) has been expressed in terms of latitude and longitude. The curvature of the earth's surface has been taken into account for all calculations involving distances between sources and gages.

2.4 PLUME DEPLETION

Plume depletion is the generic term for the removal of material from the air by deposition on the landscape (as opposed to simple dilution). Plume depletion occurs by four mechanisms: dryfall, washout, rainout, and degradation. In dryfall, the material settles to earth under the influence of

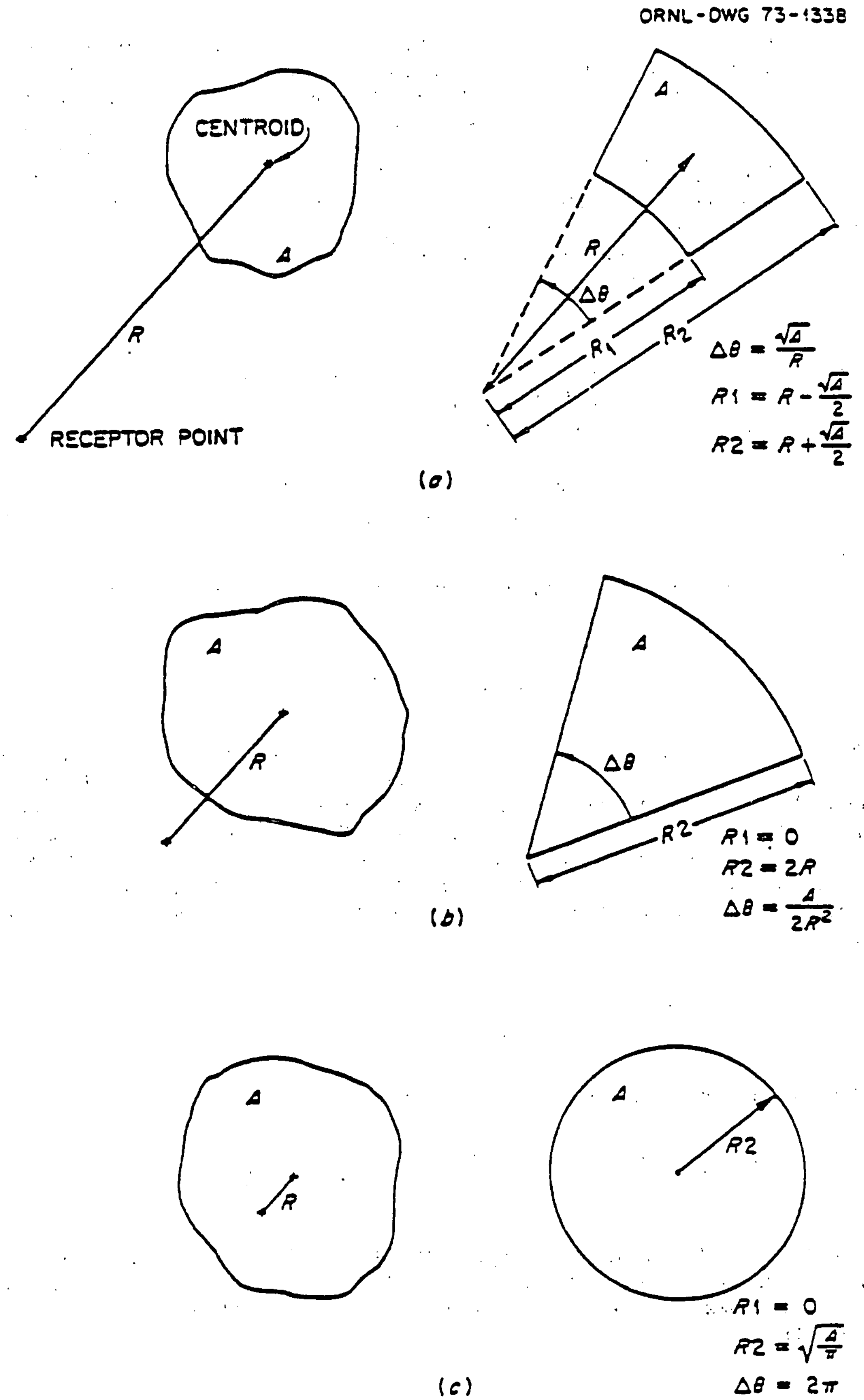

Fig. 4. Initial and transformed area sources. Part a, $\sqrt{A}/R < 2$; part b, $2 < \sqrt{A}/R < \sqrt{4\pi}$; part c, $\sqrt{A}/R > \sqrt{4\pi}$.

gravity. In washout, the material passes under a rain cloud and is scavanged from the air by the raindrops. In rainout, the material rises into a cloud and forms the nuclei for the formation of raindrops with the material being carried to earth inside the resulting raindrops. This model considers only the washout and dryfall deposition processes because rainout generally occurs at heights above that of the planetary boundary layer. Plume-depletion processes reduce the effective source strength of the plume at increasing distances from the injection point. This effective reduction of the plume source strength has been handled in a perturbative fashion by first calculating what the concentration and subsequent deposition values would be if there were no diminution of the source strength. This zero-order estimate of the concentration is then reduced by the amount of material that has been deposited. The modeling of the two major deposition mechanisms are described below.

2.5 DRY DEPOSITION

The atmospheric concentration of a particular species under consideration can be calculated with Eq. (2). This concentration at ground level for an effective stack height h with dispersion in both the z-direction and the transverse y-direction can be calculated as

$$q = \frac{Q}{2\pi\sigma_y \sigma_z u} \exp\left\{-\frac{y^2}{2\sigma_y^2} - \frac{h^2}{2\sigma_z^2}\right\} . \tag{10}$$

This atmospheric concentration leads to an aerial deposition given by the following formula

$$\omega = v_g \cdot \frac{Q}{\pi\sigma_y\sigma_z u} \exp\left[-\frac{y^2}{2\sigma_y^2} - \frac{h^2}{2\sigma_z^2}\right] , \tag{11}$$

where the deposition velocity v_g has been multiplied by the atmospheric concentration to yield the deposition per unit area per unit time. The variation of this concentration and the consequent deposition in the transverse y-direction is Gaussian, and an effective measure of the width of the plume is the value of the dispersion parameter σ_y. Consequently, the transverse variation is integrated out, and the values of the atmospheric concentration and the deposition are averaged over the one-sixteenth of a circle included in each of the sixteen subcardinal directions. The dryfall deposition can be included in a perturbative sense by calculating the rate of change of the effective source strength as a function of distance:

$$\frac{dQ}{dx} = -\int \omega dy . \tag{12}$$

Substituting the value for the aerial deposition determined above, we obtain

$$\frac{dQ}{dx} = -\int_0^{y'} \frac{v_g Q \exp(-h^2/2\sigma_z^2)}{\pi\sigma_y\sigma_z u} \exp(-y^2/2\sigma_y^2) \; dy . \tag{13}$$

Those terms that are not a function of the lateral direction y can then be brought outside the integral. Because of the small contribution of the concentration in the region outside of 2σ in lateral distance, the integral may be extended from minus infinity to plus infinity without introducing large errors. This integration yields

$$\frac{dQ}{dx} = -v_g \sqrt{\frac{2}{\pi}} \frac{Q \exp\left(-h^2/2\sigma_z^2\right)}{\sigma_z u} \quad . \tag{14}$$

The solution for an effective source strength is

$$Q = Q_o \exp\left[-\sqrt{\frac{2}{\pi}} \left(\frac{v_g}{u}\right) \int_0^x \frac{\exp\left(-h^2/2\sigma_z^2\right)}{\sigma_z} dx'\right] \quad . \tag{15}$$

Note that the above equation includes the still basically Gaussian shape in the form of an indefinite integral from the point of emission $x'=0$ to the point of calculation at $x'=x$. This integral cannot be analytically evaluated because of the dependence of the dispersion coefficient σ_z on the distance x'; it must be evaluated numerically. This formulation of the effective dryfall source strength is incorporated into an equation given at the end of the next chapter.

2.6 WET DEPOSITION

The depletion of material by washout [Englemann (1963)] can be taken to be proportional to the amount of material in the plume. This relationship is displayed in the differential equation in which the time rate of depletion is proportional, through the constant λ, to the material remaining in suspension:

$$\frac{dQ}{dt} = -\lambda Q \quad . \tag{16}$$

Again, this equation can be cast in a form that can be readily integrated:

$$\int \frac{dQ}{Q} = \int -\lambda dt \quad , \tag{17}$$

to yield the exponential form,

$$Q = Q_o e^{-\lambda t} \quad . \tag{18}$$

In turn, the transit or residence time of the material in the suspended state can be approximated as

$$t = \frac{x}{u} \quad . \tag{19}$$

Thus, the effective source strength, as modified by washout, depends on distance and wind speed in an exponential decay:

$$Q = Q_o e^{\frac{-\lambda x}{u}} \quad . \tag{20}$$

2.7 OTHER DEPLETION PROCESSES

The plume may also be depleted by changes that diminish the quantity of the pollutant species of interest (e.g., radioactive decay or photolysis). A simple exponential decay mechanism has been added to allow for species change when the rate of such change is known. For each pollutant, the input parameter required is the "effective half-life" in seconds, which is the time required for a given quantity of pollutant to be reduced to one-half its original concentration. If no half-life is entered, an essentially infinite half-life of 10^{12} sec is assigned by default. For some applications, it may be desirable to follow the concentration of the "daughter" species formed as a result of degradation of a "parent" pollutant. Therefore, an additional input parameter has been added for each pollutant. No provision has been made for following subsequent decays (i.e., the production of "granddaughters").

2.8 BACKGROUND

Some pollutants may have background concentrations in the vicinity of the receptor gages. Because the total concentration, including background, of pollutant at a particular site is often of interest, the option of inputting background values for each pollutant at each gage has been added. These background values are then added to the concentration values computed for each gage from the sources nearby.

2.9 SUMMARY OF MODEL CALCULATIONS

The diminution of source strength by dryfall and washout is incorporated into the Gaussian plume formulation along with the frequency table for occurrence of stability type, wind direction, and wind speed by multiplying the equation for a single point source with unidirectional wind flow by the appropriate factors:

$$X_i(x,\theta) = \sum_{p=1}^{N_s} \sum_{r=1}^{N_w} \frac{2.032 F_{pr}(\theta)\overline{Q}_{ipr}(x)}{\sigma_p(x) u_r x} \exp\left[\frac{-h_{pr}^2}{2\sigma_p^2(x)}\right] . \tag{21}$$

Here,

$X_i(x,\theta)$ = ground-level air concentration of pollutant i in direction θ at a distance x from the source,

θ = one of the wind directions (N, NNE, NE, etc.),

r = one of eight wind-speed classes,

$F_{pr}(\theta)$ = fraction of time during which the wind blows from direction sector θ with wind speed class r and stability class s,

$\overline{Q}_{ipr}(x)$ = point-source strength for pollutant i modified by depletion from fallout and washout occurring at distances less than x,

N_s = number of stability classes,

N_w = number of wind speed classes,

$\sigma_p(x)$ = vertical dispersion parameter appropriate for stability class p and distance x,

h_{pr} = effective stack height, and

p = one of six wind-stability classes (A, B, C, D, E, and F) changing from extremely unstable to moderately stable.

The form given above is then generalized to include many point sources at many receptor sites by summing over the contributions to a given receptor by all the point sources to give

$$X_l = \sum_{p=1}^{N_s} \sum_{r=1}^{N_w} \sum_{j=1}^{N_j} \frac{2.032 F_{pr}(\theta_j) Q_{lpr}(x_j)}{\sigma_p(x_j) u_r x_j} \exp\left[\frac{-h_{pr}^2}{2\sigma_p^2(x_j)}\right] \tag{22}$$

where N_j is the number of point sources. Note the dependence on distance that is implicitly contained in the dispersion coefficients σ. The somewhat complicated-looking formalism simply implies that contributions from many different point sources have been included, that the wind flows from a given direction with a given fractional occurrence during the climatological period of reference (which is generally taken to be one month), and that the transverse dependence of the atmospheric concentration has been integrated out and assigned to the sixteen subcardinal directions. Thus the material is assumed to be uniformly distributed within each of these subcardinal directions during the time that the wind direction is from the point source to the receptor.

3. THE ATMOSPHERIC TRANSPORT MODEL PROGRAM

3.1 GENERAL INFORMATION

The code for calculation of the results described above has been written in FORTRAN IV, which uses the most generally available type of FORTRAN compiler. In particular, the FORTRAN IV versions described here can be readily implemented on most IBM, CDC, and DEC machines with, in some cases, no changes to the source program. We have attempted to maintain this generality of the source programming to keep the Atmospheric Transport Model readily transferable from our site to other users. The current submodel is relatively simple in its computing-facility requirements, storage requirements, and machine running time.

3.2 STRUCTURE OF THE PROGRAM

The structure of ATM is illustrated in Fig. 5. The function of the main portion is to read in and report out the input data that are fed to the submodel to describe the wind frequency table; the source strengths; the locations of point sources, line sources, area sources, and resuspension sources; and the sites of the particular receptor points at which the calculated values of deposition and concentration are desired. The more detailed subprogram GEOMET is called, which calculates the geometry relating receptors and sources. In addition, the fraction of time during which washout can be expected to occur is calculated by the subroutine FRXTRN and stored for later use in other subroutines. In this subroutine the default values can be set from available climatological data for average rainfall intensity and the fraction of the time during which rainfall occurs. ATM also includes a subroutine WNDSCE for calculating resuspension contributions from area sources, such as tailing piles; however, this capability has not yet been evaluated in detail, and this part of the model is unvalidated but potentially useful.

The detailed input data and the calculated geometric relationships are passed to a subroutine called DCAL, which stands for "detailed calculations," in which the specific calculations given above for atmospheric concentration and deposition are performed. The subroutine DCAL calculates the dispersion coefficients by calls to the function SIGMA and calculates the integral in the subroutine QQP by means of a Simpson's integration (SIMPUN) taken from Westley and Watts (1970). Values for washout coefficients are calculated in the subroutine WASH.

For short-term contributions to atmospheric concentrations, the subroutine MAXCON can be employed on an hourly scale. This subroutine retains the dependence of the plume concentration on the lateral dispersion coefficient σ_y and calculates the lateral dispersion coefficient by calls to subroutine SIGA. The hour-by-hour calculation of the toxicant concentration by MAXCON requires a considerable amount of computer time; the user would be well advised to consider carefully which calculations are the most germane.

In general, the wind speeds that are input to the model have been measured near the surface and are not applicable to elevated sources, such as smoke stacks. For each point source, the wind speeds at the source height are computed with a power-law relationship proposed by Irwin (1979). The equation has the form

$$u(z) = u \cdot \left(\frac{z}{z_o}\right)^p \quad , \tag{23}$$

where u is the wind speed measured at a height z_o (generally 10m) and $u(z)$ is the computed speed at height z. Irwin found that the exponent p was primarily a function of stability class, with a slight dependence upon surface roughness. We have chosen to use the approach of the EPA RAM Model

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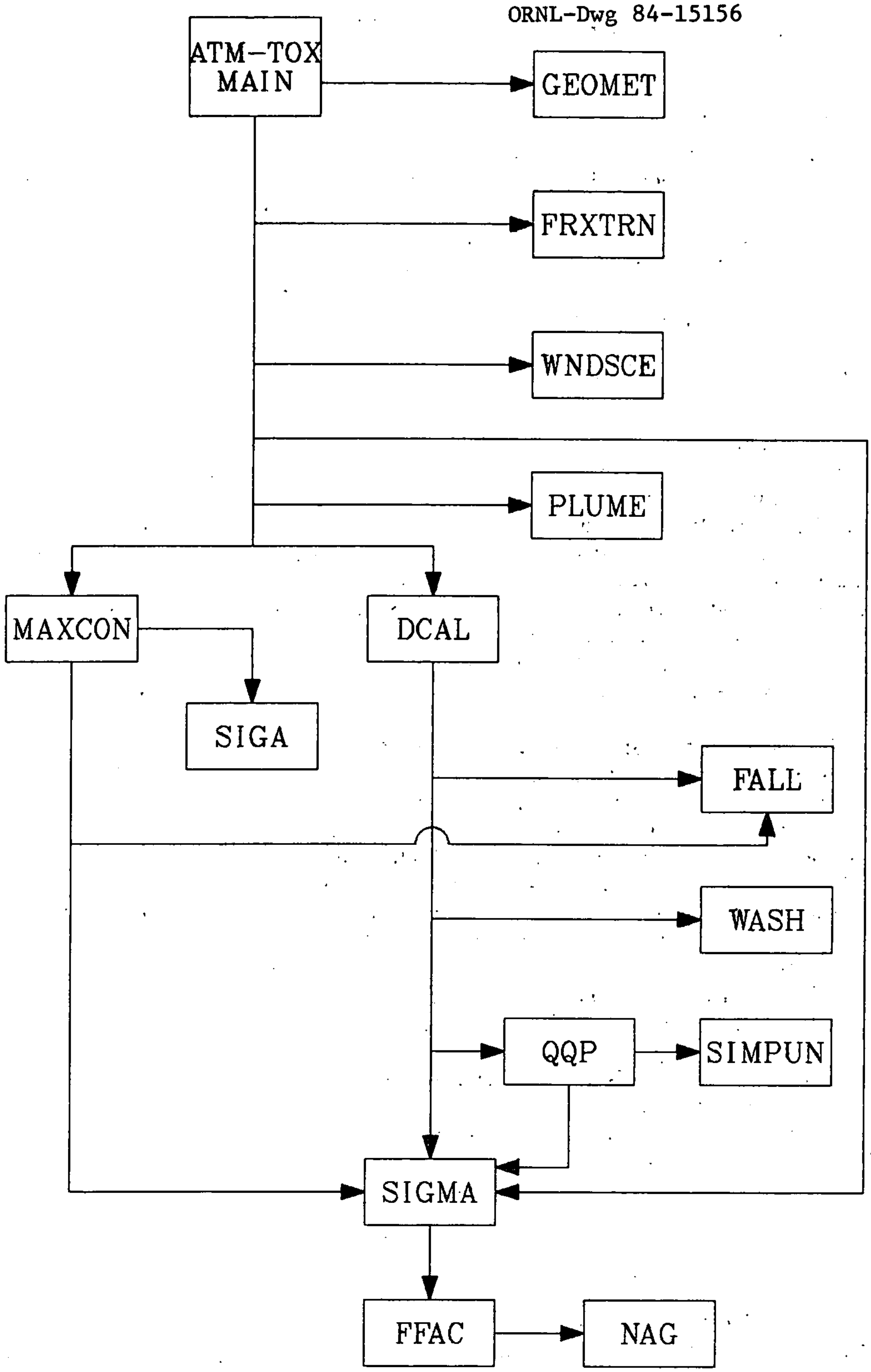

Fig. 5. Structure of the Atmospheric Transport Model.

(Turner and Novak, 1978) and use two sets of exponents, one for rural and the other for urban conditions. These sets are shown in Table 1.

Table 1

Exponents for Wind Profile

Stability Class	*p* (urban)	*p* (rural)
A, B	0.15	0.07
C	0.20	0.10
D	0.25	0.15
E	0.40	0.35
F, G	0.60	0.55

The rural exponents are used if the Briggs dispersion parameters are specified (KDISP = 2 or 3), while the urban exponents are used with the Pasquill-Gifford dispersion parameters.

For each period of interest, values for the afternoon (HTA) and nocturnal (HTN) mixing heights are input to the model to be used by subroutine DCAL to allow a correction for plume trapping. To account for some of the diurnal variation of mixing height, values are computed for each stability class according to Table 2, again with the approach of the EPA RAM Model, (Turner and Novak, 1978).

Table 2

Variation in Diurnal Mixing Height

Stability Class	Mixing Height
A	1.5*HTA
B, C	HTA
D day	HTA
D night	(HTA+HTN)/2
E, F, G	HTN.

Because the order of use of the subroutines varies with application, discussions of each portion of the program are given below in alphabetic order. Constant reference should be made to Fig. 5, which shows the structure and relative order of use of these subroutines. All of the input is done in the main section of the program with subsequent transferral of these input data to the needed subprograms. Although the operations of the subroutines are highly structured, they can be modified by the user if necessary.

3.3 PROGRAM AND SUBROUTINE FUNCTIONS

The functions of the program ATM and its subroutines are:

ATM	The section of the program that reads in the data set, calls subroutine GEOMET and either DCAL or MAXCON, and prints out the input data.
DCAL	(Detailed Calculations) Calls most of remaining subroutines tp calculate required output.
FALL	Calculates terminal and deposition velocities for particles and deposition velocity for gases.
FFAC	Calculates Smith's roughness factors.
FRXTRN	(Fraction of Time it Rains) Inserts monthly rainfall information into the program.

GEOMET	Calculates source-to-receptor gage distances and directions, given the latitude and longitude of each source and receptor.
MAXCON	(Maximum Concentration) Finds the single highest concentration possible at a specific location from a number of point sources and specifies "worst" condition of wind speed, wind direction, month, and stability condition.
NAG	Five subroutines (E02CBF, E02AEF, X02AAF, X04AAF, and P01AAF) from the NAG library for doing a bicubic spline interpolation.
PLUME	Calculates plume rise parameters.
QQP	Calculates attenuation of source strength from deposition, washout, or fallout.
SIGA	(Sigma Azimuthal) Calculates distances of receptor to plume centerlines and appropriate horizontal dispersion parameters.
SIGMA	Calculates vertical diffusivities.
SIMPUN	(Simpson's rule) Employed by QQP to calculate the integral describing attenuation of the material source strength.
WASH	(Washout) Calculates washout coefficients for particles and gases.
WNDSCE	(Windblown Sources) Calculates resuspension of materials by the wind.

3.4 SUBROUTINE DESCRIPTIONS

ATM

The main program has two basic functions: to read in the bulk of the data set and to process the data set for more efficient handling in the subroutine DCAL. A data set is read that establishes a monthly or annual matrix of wind speeds, wind velocities, and stability categories. The subprogram then calculates and stores these data as the fraction of time each element of that matrix occurred.

Subroutine DCAL

This subroutine is the workhorse of the entire program. Its function is to call the required subprograms (except MAXCON and SIGA) and to print the results.

Equation (22) estimates the concentration for point sources and calculates the total point source concentration.

The subroutines WASH and FALL calculate wet and dry deposition, respectively. Dry deposition is calculated as

$$\omega_i(x,\theta) = \sum_{p=1}^{N_s} \sum_{r=1}^{N_w} \frac{F_{pr}(\theta)}{\sigma_p(x)u_r x} \; 2.032 v_i W_f \; \exp\left[\frac{-h^2}{2\sigma_p^2(x)}\right] Q_{ipr}(x) \quad , \tag{24}$$

where

$\omega_i(x,\theta)$ = deposition rate of pollutant i, in direction θ, at a distance x from the source;

W_f = fraction of time in which only dry deposition occurs;

v_i = deposition velocity of pollutant i.

Similarly, wet deposition (washout) is calculated as

$$\omega_i(x,\theta) = \sum_{p=1}^{N_s} \sum_{r=1}^{N_w} \frac{F_{pr}(\theta)}{\sigma_p(x)u_r x} \; 2.453 \lambda_i W_w Q_{ipr}(x) \; \sigma_p \; (x) \quad , \tag{25}$$

where

W_w = fraction of time both washout and dry deposition are occurring and

λ_i = washout coefficient of pollutant i.

The program calculates the wet and dry deposition at each receptor from each source and then sums up the contributions for each receptor. Two mixing heights (afternoon and nocturnal) are read into the program. Mixing heights for each stability class are then computed as shown in Table 2. These mixing heights are used in DCAL to correct the pollutant concentration for plume trapping. The equation of Bierly and Hewson (1962), as described by Turner (1970), is used.

Point, area, and line sources are treated virtually identically except for windblown sources (which are a subgroup of the area sources). For point, area, and line sources, the plume is normally assumed to "tilt" at the terminal velocity of the particle in question. For gases, the plume is assumed to not tilt. The deposition velocity is assumed equal to the terminal velocity if the terminal velocity exceeds 0.01 m/s; otherwise, the deposition velocity is assumed to be 0.01 m/s.

The type of vegetative cover is important because it governs the amount of dry deposition. The vegetative cover right at the gage may be different from the general type of cover assumed for the area the gage represents. Therefore, even though the program initializes each gage to the general type of ground cover (SURF(I) = KCOVER; I = gage number), each surface type may be overridden after DO loop 10 in subroutine QQP.

True area sources are fields and forests emitting water vapor, ammonia, etc. Generally, however, areas that have numerous points of emission, that are low in height, and that are more or less uniform in strength (such as household emissions of coal smoke) are classified as area sources. The ATM user must exercise judgment concerning the locations, boundaries, and source strengths of such areas.

Numerous (separate) point sources may also be included within the boundaries of an area source. In the GEOMET subroutine, the boundaries of the area sources are idealized and apportioned into the appropriate wind-direction sectors. Because the area within a given sector may still be quite large, the program breaks each area within a sector into three regions of equal source strength at increasing distances from the receptor. (See Fig. 6.) By so doing, the problems with using a single centroid (point source) approximation for an area source are substantially mitigated. Nevertheless, the subject of area sources is complex, and the reservations expressed in the discussion of the ATM subroutine should be carefully considered.

The estimate of the concentration and deposition from windblown sources is analyzed with a variety of methods. Sutton (1932) derived a model that served as a mainstay for concentration estimates for many years. It was well verified for short distances and low source heights and had the advantage of being integrable. Although Sutton used a different set of dispersion parameters from what is used here, it is possible to use Csanady's (1958) form of the Sutton approximation to fit the present model.

$$\omega_i(x,\theta) = \sum_{p=1}^{N_s} \sum_{r=1}^{N_w} \frac{1.016 Q_s F_{pr}(\theta) F_d \delta A f}{\sigma_p(x) u_r x} \exp\left[\frac{-fx/u_r - h}{2\sigma_p^2}\right] \tag{26}$$

$$\times \left[2 - \frac{2}{(1 - \frac{n_p}{2})(\frac{u_r - h}{xf} - 1) + 2}\right],$$

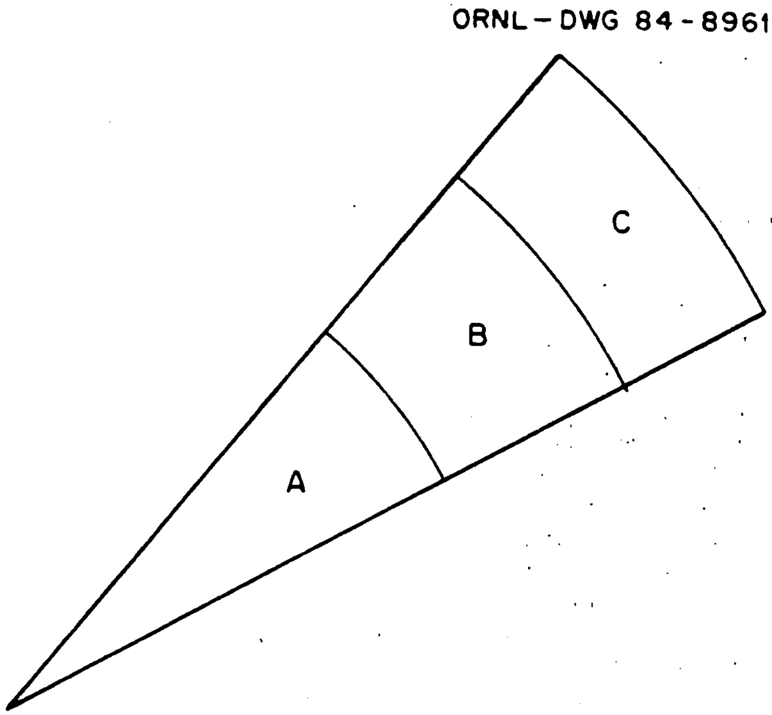

Fig. 6. Division of sector into regions having equal source strengths.

where

Q_s = area source strength (velocity dependent),

f = settling velocity of dust particle (m/s),

$$n_p = -\frac{2x}{\sigma_{p,z}} \frac{d\sigma_p}{dx} + 2 ,$$

h = source height (m),

F_d = fraction of time the windblown source remains dry, and

δA = element of area.

The line-source treatment is, again, based on the Gaussian point-source calculation, but each line source within a sector is broken into nine centroids to approximate a continuous line source.

Subroutine FALL

The present model includes effluent removal by four processes: (1) fallout, (2) deposition, (3) washout and (4) degradation. The first two processes are generally termed "dry removal," and the third is termed "wet removal." Dry removal is covered by subroutine FALL, and wet removal by subroutine WASH.

The subroutine FALL assigns particles a terminal velocity and deposition velocity according to Stokes's law. The terminal velocities are later used to calculate plume tilt. Gases are assigned a deposition velocity of 0.01 m/s and a terminal velocity of 0, unless otherwise specified. Later in subroutine DCAL, the particles are assigned a minimum deposition velocity, and the calculated concentration of both gases and particles are reduced at varying rates in subroutine DCAL and function QQP.

The two methods of effluent removal treated by FALL, fallout and deposition, are often confused because they both have the units of velocity. In fallout, a particle falls of its own weight. The driving force is gravity and applies throughout the atmosphere. In its fall, a particle reaches a terminal velocity, the fastest speed it can reach because of its density, cross-sectional area, and aerodynamic drag. Deposition is a surface phenomenon independent of gravity. It is the product of the concentration of the emission, the downwind speed of the emission near the surface of the earth (the deposition velocity), and an adsorption factor. Thus gases, such as sulfur dioxide, that deposit on a surface have a deposition velocity even though they have no terminal velocity.

For particles, the program assumes that material that is falling out will have a vertical settling velocity given by Stokes's law:

$$V_s = D^2 \cdot S \cdot 3 \times 10^{-5} , \tag{27}$$

where

V_s = terminal velocity of particle (m/s),

D = diameter of the particle (microns), and

S = density of particle (gm/cm^3).

The constant 3×10^5 is applicable at 18°C. One would expect, for example, that V_s would appreciably diminish as the size of the turbulent elements increased. Nevertheless, the assumption that an aggregate of particles will behave with a mean terminal velocity has been used in plume work since Schmidt (1925). The theoretical objections are not very restrictive in practice, however, since a 10-micron particle of unit density is calculated to fall only twelve meters in one hour. For very large or very dense particles, where the terminal velocity becomes important, the effect of turbulence on slowing terminal velocities is apparently not very great for average dustfall (Csanady, 1972).

When particles are of the magnitude of 100 microns in radius and about 2.5 gm/cm^3 in density, the plume will sink under the influence of gravity at the rate of approximately one meter per second. The centerline of the plume then reaches the surface in less than one hour. Because the centerline of the plume contains the maximum concentration, it is not "conservative" to ignore fallout (i.e., terminal velocity).

In the absence of turbulence, terminal velocities and deposition velocities would remain very similar, but turbulent air rapidly increases the deposition velocities of small particles (i.e., those below 10 microns), which are the most abundant under certain circumstances (*ca.* 10^{12} particles per cubic meter of air). The program approximates the increased deposition velocity by assigning a deposition velocity of 0.01 m/s for terminal velocities below this value.

Deposition is generally given in the units of velocity as introduced by Chamberlain (1953).

$$v_g = \omega / X_o\ (x,y)$$

where,

v_g = deposition velocity (m/s),

ω = rate of deposition (parts/m^2/s), and

$X_o(x,y)$ = concentration at the surface (parts/m^3).

Here,

$$X_o\ (x,y) = X\ (x,y,z=o) = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{y^2}{2\sigma_y^2} - \frac{h^2}{2\sigma_z^2}\right] \tag{28}$$

The physical processes that determine the magnitude of the deposition velocity are complex and not thoroughly understood. They depend on the material being deposited, the receptor surface, and the turbulence. The present program provides a method for calculating the deposition velocity of a gas from the turbulence type and molecular diffusivity, as suggested by Chamberlain (1953):

$$v_g = a\ K_z / \ln(K_z/D) \quad ,$$

where

K_z = diffusion constant (m^2/s),

D = molecular diffusivity (m^2/s), and

a = 1.0 (m^{-1}).

Unfortunately, sufficient experimental verification is lacking for uncritical acceptance of these calculations. The program has a default value for v_g of 0.01 m/s, a value found to be acceptable for SO_2. The user may choose the Chamberlain calculation or the default value or may insert another value in place of the default value.

Sehmal and Hodgson (1974) give excellent theoretical and experimental values of particulate deposition should the reader care to pursue the matter further.

Subroutine FFAC

Subroutine FFAC calculates the *F* factor used in subroutine SIGMA to adjust the dispersion parameters as suggested by Smith (1973) for variations in surface roughness. Data from Fig. 5 of Smith's paper (reproduced as Fig. 6.13d by Pasquill, 1974) were fit using a bicubic spline expression (NAG, 1981). The parameters from this fit are given in the DATA statements of FFAC. This subroutine calls subroutine E02CBF from the NAG library to calculate *F* as a function of roughness length and distance from the source to the receptor gage.

Subroutine FRXTRN

Subroutine FRXTRN reads the weather data and divides the number of hours of measurable precipitation (0.01 inch or more) by the total hours in each month to yield the fraction (FRACT) of time it rains each month. The total rainfall divided by the number of hours of rainfall is the average rate (AVRAT) used in the program. This rate is used to determine how much airborne pollution is washed out of the air by precipitation. As explained in subroutine WASH, more detailed programming may prove necessary where wind direction and rainfall are highly correlated.

Subroutine GEOMET

The distances and angular relationships between source locations and receptor gages are calculated in subroutine GEOMET. A source point, a receptor gage, and the North Pole form the end points of a triangle on the surface of a sphere. Both the distance between the source and the receptor gage and the angular direction from north for the gage are computed from the latitudes and longitudes of source and receptor and the relationship between the sides and angles of a spherical triangle.

Subroutine MAXCON

Subroutine MAXCON uses Eq. (2) and the subroutine SIGA to find the set of circumstances that produces the greatest concentration of material during an hour at one or more locations from a number of point sources. This routine consumes a large amount of computer time if 360° are scanned at one-degree intervals (e.g., calculations for two gages and four point sources require about 20 min of computer time on an IBM 360/91).

No removal mechanisms (washout or deposition) are used in this subroutine, primarily for economy of computer time. This subroutine would usually be employed to predict deposition relatively near large stacks where that deposition could not contribute a loss of emission inventory of more than a few percent. If deposition is thought to be a major consideration, however, the function QQP with one-degree resolution should be employed in MAXCON in the same relative location as in subroutine DCAL. To save computer time, a run of five-degree intervals can be used to determine the most troublesome directions, with one-degree sweeps used on successive runs. The subroutine prints the period, wind direction, speed, and stability conditions that produce the maximum hourly concentration.

NAG Subroutines

Three subroutines (E02CBF, E02AEF, and X04AAF) and two functions (X02AAF and P01AAF) from the Numerical Algorithms Group (NAG, 1981) library are used by subroutine FFAC to do a bicubic spline interpolation of Smith's *F* factor of roughness.

Subroutine PLUME

Subroutine PLUME calculates the plume rise from point sources. The plumes are considered to rise as a result of the buoyancy and momentum allowed by the data input. Total height of rise is restricted, however, to 1500 meters, a typical height of the tropospheric "mixing depth."

The emitted material rises above the stack height, and that distance it goes up is called the plume rise (expressed in meters) (Briggs, 1970).

$$h = h_o + \Delta h ,$$

where,

$$\Delta h = 1.6(F_B)^{1/3}u^{-1}(3.5x*)^{2/3} \text{ for } A, B, C, D \text{ stabilities, where}$$

$$x* = 14\ m\ (F_B/m^4/s^3)^{5/8}, \text{ if } F_B<55m^4/s^3, \text{ and} \tag{29}$$

$$x* = 34\ m\ (F_B/m^4/s^3)^{2/5}, \text{ if } F_B>55m^4/s^3, \text{ or}$$

$$\Delta h = 2.9\left(\frac{F_B}{us}\right)^{1/3} \text{ for } E \text{ and } F \text{ stabilities, where}$$

$$F_B = gWr^2\frac{T_S - T_E}{T_E}, \text{ in which}$$

g = gravitational acceleration (9.8 m/s^2),

W = stack gas ejection velocity (m/s),

r = radius of the stack (m),

T_S = stack gas temperature (K),

T_E = ambient air temperature (K),

s = $\frac{d\theta}{dz}\left(\frac{g}{T_E}\right)$, and

$\frac{d\theta}{dz}$ = potential temperature gradient.

The plume-rise parameters used in the sample run are given below:

T_S = 350 K,

T_E = 280 K,

r = 1.5 m

W = 10m/s.

$\frac{d\theta}{dz}$ = 1K/100m (approximately true for slightly stable or moderately stable conditions), which results in

Δh = $\frac{429}{u}$ (m) for A,B,C,D stabilities (i.e., PKAPPA = 429), or

Δh = $\frac{157}{u^{1/3}}$ (m) for E and F stabilities (i.e., QKAPPA = 157).

In the previous version of ATM, the quantities PKAPPA and QKAPPA were input parameters. In the current version, they are computed within the program.

Although we have not attempted to model the behavior of a plume in complex terrain, we have included a correction to the plume height when a receptor gage elevation, $h(x)$, is not the same as the base of the point sources. The correction when $h(x) > 0$, as shown in Fig. 7, is that used in the Environmental Research and Technology's Point Source and Diffusion Model (Egan, 1975). A summary is given in Table 3. A correction to the plume rise calculated by PLUME is computed as h_p in subroutine DCAL.

Table 3

Correction to Plume Rise for Terrain Influence

Receptor Elevation $h(x)$	Plume Rise (h_p)
0	$h\ (=h_o + \Delta h)$
$0<h_l<h$	$h - h_1/2$
$h<h_2$	$h/2$
$h_3u<0$	$h + \lvert h_3 \rvert$

Function QQP

As wet and dry deposition attenuate the strength of the plume downwind, the model calculates the fraction of material remaining by using the function QQP. As defined in the discussion of subroutine FALL, the deposition rate over any given area is

$$\omega = X_o(x,y) \cdot v_g \quad ,$$

where X is the concentration at the surface and v_g is the deposition velocity.

Since the deposition ω removes material from the plume, the amount removed while the plume traverses the distance dx must be integrated across the width of the plume (direction y):

$$\frac{dQ}{dx} = - \int_{-\infty}^{\infty} X_o\ (x,y) \cdot v_g\ dy \ . \tag{30}$$

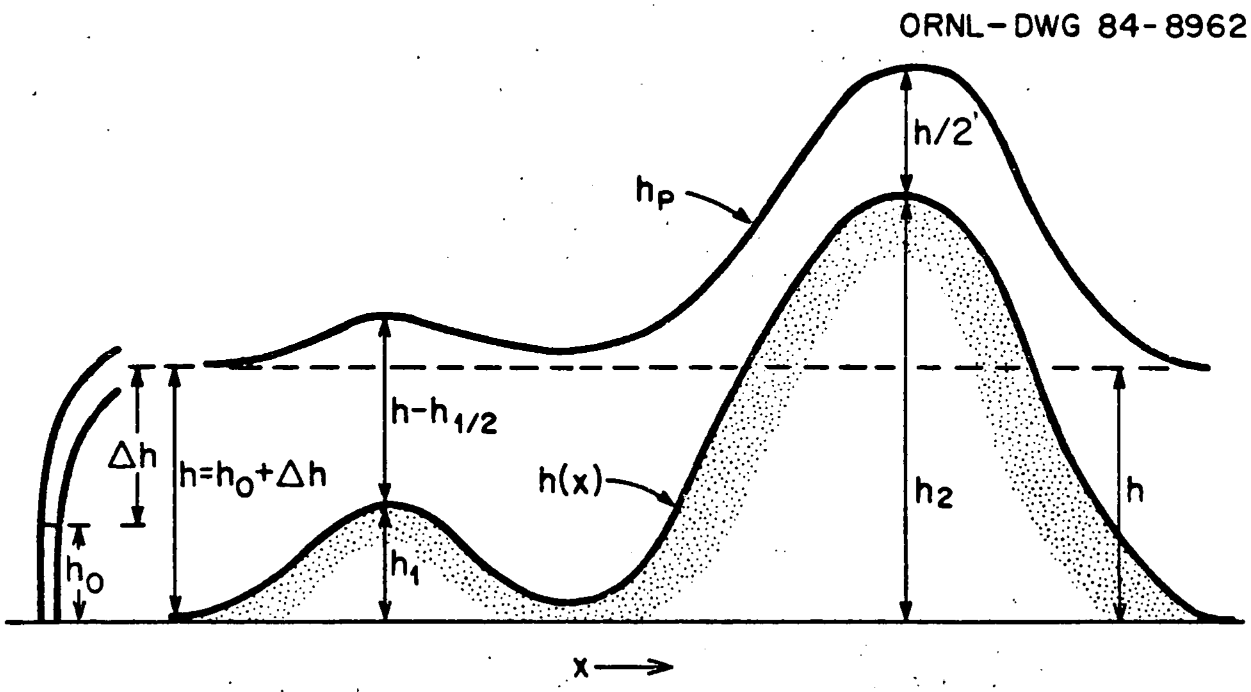

Fig. 7. Effect of terrain influence upon plume height.

From Eq. (30) we may write

$$\frac{dQ}{dx} = \frac{-Qv_g \exp\left(-h^2/2\sigma_z^2\right)}{\pi u \sigma_y \sigma_z} \int_{-\infty}^{\infty} \exp(-y^2/2\sigma_y^2)\ dy\ , \tag{31}$$

which yields

$$\int \frac{dO}{Q} = -\sqrt{\frac{2}{\pi}}\ \frac{v_g}{u} \int \frac{\exp(-h^2/2\sigma_z^2)}{\sigma_z}\ dx + ln\ Q_o \tag{32}$$

and

$$Q = Q_o \exp\left[-\sqrt{\frac{2}{\pi}}\ \frac{v_g}{u} \int_o^x \frac{\exp(-h^2/2\sigma_z^2)}{\sigma_z}\ dx'\right]\ , \tag{33}$$

where Q is the effective source strength downwind and Q_o is the original source strength.

The integral in this last equation is calculated by Simpson's rule in subroutine SIMPUN. For dry deposition and for dry periods,

$$QQP = Q/Q_o\ .$$

Also,

$$dQ_w = -\lambda Q_w dt\ ,$$

where λ is the washout coefficient in reciprocal seconds and t is the time of travel in seconds. From this equation comes

$$Q_w/Q_{w_o} = \exp(-\lambda t)\ .$$

The time of travel is estimated by

$$x = ut\ ,$$

where u is the wind speed in the x direction. Thus,

$$t = x/u\ ,$$

and

$$Q_w/Q_{w_o} = \exp\left(-\lambda x/u\right)\ .$$

The dry deposition process is assumed to operate during periods of washout, also, so for washout plus dry deposition

$$QQP = Q/Q_o + Q_w/Q_{w_o} \ .$$

Attenuation of material by dry deposition is rapidly increased over a forest. Sehmal and Hodgson (1974), Slinn (1972), Hori (1953), and Baumgartner (1956) have reported effective deposition velocities of more than 0.1 m/s over forested regions. The causes of this increased deposition are complex and not fully understood. Certainly, the increased surface area itself leads to higher total deposition, though not an increase in v_g. The boundary-layer physics and the wind fields of a forest obviously differ grossly from respective grassland parameters. In this code, however, we choose not to alter v_g itself, but to introduce an "effective area" argument (i.e., to approximate the effective increase in deposition by ascribing a net increase of surface area over that of grassland). Thus, if one assumed that the deposition was eight times as much as that over a grassy plain, one would assign KCOVER = 8, and function QQP would multiply each surface increment in Simpson's rule by a factor of eight. Should the plume travel over heavily forested land and then an equal amount of grassland, the user might assign a value of KCOVER = 4 or KCOVER = 5. KCOVER can also be set to zero, if no deposition is expected.

A specific KCOVER can be assigned to each appropriate distance increment, or the model can specify the cover type (by a subprogram similar to the area source modifications in the MAIN Program), but the penalty in computer time is large if many area sources are used.

As explained in subroutine FALL, heavy particles settle out in the aggregate at a rate approximating Stokes's law. The net effect of this settling is to tilt the plume's centerline downward. This downward tilting is calculated in this routine for particles with a terminal velocity greater than 0.01 m/s. These particles are assumed to have a deposition velocity equal to this terminal velocity. Particles which settle at a rate of less than 0.01 m/s are assigned a deposition velocity of 0.01 m/s in subroutine DCAL. (See the description of that subroutine.) For conservatism, these particles are assigned a new terminal velocity of zero in subprogram QQP. With a terminal velocity of zero, the particles are assumed not to leave the plume, and the effective strength of the source (which is calculated in QQP) will always be too high and therefore conservative.

There have been many objections, on theoretical grounds, to using the Gaussian-plume model for deposition estimates. It has been pointed out that removal from the bottom of a Gaussian plume automatically changes the basic assumption that it remains Gaussian in shape. Defenders of the method argue that vertical mixing is sufficient to support a Gaussian approximation and, as is pointed out in the discussion of the basic calculations, that the assumed Gaussian shape cannot be rigorously defended in any case. Horst (1974) compared the effects of a mathematical model that removed only surface material with the effects of one that removed the inventory from the entire plume, as does this model. The comparison indicates that for v_g/wind speed < 0.01 the two models agree well for stabilities A to D. For stability F and/or v_g/wind speed > 0.01, the errors increase as v_g increases. Therefore, one should exercise caution in interpreting the results when forest cover is assumed. On the other hand, the complexities of flow over (and through) a forested region are not fully understood, and Horst's corrections are unsubstantiated in this case. The investigator may do well to compare the results of the present model for KCOVER = 1 and KCOVER = 10 and assume these bracket the true value.

Subroutine SIGA

This subroutine, Sigma Azimuthal, not only computes the horizontal dispersion parameters (SIGY) required in Eq. (2) but also calculates the minimum distance (DIS) from the gage to the plume's centerline and a new distance (DIS2) from the source to the intersection of the normal with the plume.

Function SIGMA

Equation (2) includes the six basic parameters of the Gaussian plume equation: source strength, wind speed, horizontal and vertical distances from the plume's centerline, and the horizontal and vertical dispersion parameters. In subroutine DCAL, the horizontal dispersion plays no part in calculating average concentrations for extended periods. The remaining parameters either are known or can be estimated.

The vertical diffusivity σ_z is calculated by the function SIGMA.

The parameter σ_z reflects a broad range of conditions, from the height of the stack to the stability of the atmosphere. Atmospheric stability can be determined by the gradient of temperature (more accurately, potential temperature). If the temperature were to decrease at the rate of 1°C per 100 m elevation, the stability would be neutral, or a "D" (in the model a "4") category; a particle of air would be free to move by inertia only, with no buoyant forces acting upon it. Because the atmosphere is warmed by the earth's surface, primarily buoyant (unstable) conditions occur for most daylight hours. On cloudy, somewhat windy days, this instability will be slight (a "C" or "3" condition) with slow warming of the surface layers. For days with intense sunlight and little wind, very unstable ("A" or "1") conditions exist. Similarly, a night cooling of the air at the surface reverses the processes.

Superimposed upon this process are other factors, such as terrain, moisture, and synoptic weather. Note, however, that because stability conditions can change as a function of height, it is common to have unstable air at low altitudes and stable air aloft, and, conversely, very stable air at the surface with less stable air aloft.

As noted earlier, the σ_z's found in the literature are empirically based on functions of distance. The investigator has a choice of three basic methods of estimating σ_z's: the Pasquill-Gifford (Hilsmeier and Gifford, 1962) method (P-G), the Briggs (1973) method, and the Hosker (1973) method of modifying Briggs's parameters with Smith's (1973) roughness factors. The discussion below on which diffusion scheme to use is based on arguments in a paper by Gifford (1975). It should be emphasized that these are not really competing approaches. Each model is appropriate for and should be used with specific types of sources. In the atmosphere, the wind vector and diffusivities change rapidly with height, often with marked discontinuities. The σ_z's encompass the average vertical characteristics of the atmosphere for each stability, but only as they affect surface distributions.

Pasquill has indicated that his curves work well for point sources up to 100 meters in height. Based on the "Prairie Grass" (Cramer et al., 1958) experiments and other data, the Pasquill approach estimates stability well and has found wide acceptance. Its use in this program is recommended when the primary sources of pollutants are nonbuoyant and are emitted from a height of no more than 100 m. Thus if one is concerned primarily with line or area sources, the Pasquill-Gifford curves should normally be chosen. Also if point sources are from industries with nonbuoyant (or negatively buoyant) plumes, such as cement plants and industries using roof vents, the Pasquill-Gifford curves would again be applicable. Note, however, a strong caveat: σ_z must be limited to below 3200 m for the stability condition A, 1600 m for B, 800 m for C, 500 for D, 200 m for E, and 100 m for F. These limitations reflect the physical reality of the plume becoming uniformly mixed within the planetary boundary layer in the vertical direction as it proceeds downwind.

For the majority of cases, however, the primary interest will probably be in the emission of buoyant plumes from tall stacks. The behavior of such plumes is obviously different from that of plumes emitted near the ground. Initial turbulent dispersion is low, since such plumes are well above the height of maximum turbulence because of surface roughness and buoyant currents from the earth's surface are in the process of being damped. Such cases may not be suited to treatment with the Pasquill-Gifford method. Therefore, the present model calculates these vertical dispersion parameters with a slightly altered version of the method introduced by Hosker (1974), based on the works of Briggs (1973) and F. B. Smith (1973). Briggs, using TVA plume studies and the St. Louis Dispersion Study (McElroy and Pooler, 1968), produced a theoretical framework to obtain σ_z's from elevated, buoyant plumes. F. B. Smith incorporated roughness and thermal influences in a formal treatment to obtain σ_z's over a wide range of conditions. The correction to σ_z for roughness (Smith's F-factor) is calculated in subroutine FFAC as a function of distance downwind and roughness length 0.01 times the average height of solid objects (trees, buildings, etc.) intruding into the moving mass of air.

However, it may not always be possible to choose an appropriate roughness length. Therefore, the program allows a third choice, the use of the formulations for σ_y and σ_z recommended by Briggs for open-country conditions.

Normally, the difference in results from using the three sets of curves (correctly) should not exceed 10 to 20%. The greatest difference (a factor of ten) occurs at the limit of validity of the P-G curves for stability condition A and a roughness length of 0.1 meters. Otherwise, the overall differences are slight.

Subroutine SIMPUN

Subroutine SIMPUN is an "in-house" subroutine written at ORNL by J. Barish to implement Simpson's rule for integration and is used in subroutine QQP.

Subroutine WASH

Rainfall is a very important factor in removing effluent from the atmosphere. One-third or more of the suspended material below cloud level may be removed from the atmosphere by rainfall in one hour. Washout is considered to attenuate the entire plume at a uniform rate as it travels downwind. Consequently, the washout coefficient has the units of inverse time, and the material inventory downwind is given by

$$Q = Q_o \exp(-\lambda t) ,$$

where

Q_o = original source strength,

λ = washout coefficient $(s)^{-1}$, and

t = time of travel (s).

Broadly speaking, rainfall is about ten times more efficient in removing material than dry deposition. Within the first few hundred meters of a tall stack, washout is the only method of transferring material from the plume to the surface.

The program calculates washout of particles and gases from the information on the average amount of rainfall, supplied by subroutine FRXTRN.

The particulate washout estimate is based on Fig. 5.9 of Meteorology and Atomic Energy (Slade, 1968). His curves were digitized, and the washout coefficient is determined for a particular particle diameter and density by interpolation of that digitized data.

The calculation of washout for gases is done by the more direct Kelkar-Hanford curve of Fig. 5.11 in Meteorology and Atomic Energy (Slade, 1968):

$$\frac{\lambda}{D} = 5.55 \times 10^{-4} R^{0.6} ,$$

where

$\frac{\lambda}{D}$ = washout coefficient (s^{-1}),

R = rainfall rate in millimeters per hour, and

D = molecular diffusivity in cm^2/s.

The investigator should note two important items. First, the units used in FRXTRN are for rainfall in hundreths of an inch per hour (the standard U.S. Weather Service reporting unit). The conversion to millimeters is performed in subroutine WASH. Second, the average rainfall rate is used, implying that rainfall is independent of atmospheric stability, wind direction, and wind speed. In many areas a definite correlation exits between wind vectors and rainfall, however; subroutines FRXTRN and WASH as well as the main portion of the program and the calling subprogram DCAL should be modified to reflect this dependence if this effect is dominant. The National Climatic Center, Asheville, N.C., can supply rainfall and wind-vector tables upon request for most major airports for most periods.

Subroutine WNDSCE

In some places, principally in mining and smelting areas, material previously deposited may be re-entrained in the atmosphere during periods of dry windy weather. Thus a rather specialized area source is created, with source strength dependent on wind speed and the physical properties of the source itself. Subroutine WNDSCE calculates the re-entrainment, dispersal, and ultimate deposition of such material.

These properties are, unfortunately, not easily determined without additional studies. Once deposited, the physical structure of the material will change because of weathering, agglomeration, solubility, etc. The material re-entrained may not even be physically identical to that deposited. Relying principally on Bagnold's (1959) work, Mills et al. (1975) used the following model of re-entrainment.

Dust (diameter <0.1 mm) cannot be directly transported into the atmosphere by turbulent diffusion, since the drag force for such small grains is spread over a large area rather than an individual particle. The process of dust suspension is assumed to take place in three steps:

(1) The larger grains are set into motion across the surface (a process known as saltation) as the wind speed increases. The threshold velocity for the onset of saltation is given by

$$v_t = 0.575\frac{\sqrt{\sigma-\rho}}{\rho}\ gd\ \log_{10}\left|\frac{z}{k}\right| , \tag{34}$$

where

z = height of wind measurement (~1 m),

k = surface roughness during saltation (~.01m),

g = gravitational acceleration (m/s^2),

d = grain diameter (m),

σ = density of sand grains (gm/m^3),

ρ = density of air (gm/m^3).

The saltation rate q (g/m-s) may then be calculated as

$$q = \alpha C \sqrt{\frac{d}{D}} \frac{\rho}{g} (u - v_t)^3 , \tag{35}$$

where

α = $1/(5.75 \log_{10}(\frac{z}{k}))^3$

D = standard grain diameter (0.00025m),

u = wind speed (m/s),

C = constant depending upon particle size distribution (nearly uniform sand, $C = 1.5$; naturally graded sand, $C = 1.8$; wide range of grain size, $C = 2.8$).

(2) Dust is suspended by the impact of the sand particles, and so suspension is a function of the saltation rate. As a first approximation we take the suspension Q_s to be proportional to the saltation rate q:

$$Q_s = R_f q \quad .$$

R_f^{-1} has the dimension of length and could be considered roughly proportional to the average distance travelled by the sand grains between ground impacts. From the agricultural erosion data of Gillette et al. (1972), one may infer a value of R_f of about $10^{-5}m^{-1}$. This value is only a rough approximation and should be measured for the area in question.

(3) This source strength is used as an area-source input in subroutine DCAL.

4. INPUT TO AND OUTPUT FROM ATM

ENTERING DATA: AN OVERVIEW

The first data entered into ATM are concerned with the definition of atmospheric stability class: wind speeds for each wind-speed class and the wind rose for each wind-speed class, stability class, direction, and period. Data pertaining to the geographic location of the receptor gages, point sources, area sources, line sources, and wind-blown sources are next. Logical variables (switches) describe whether each gage or source is to be included in the subsequent calculations. The positions of these gages are specified in terms of latitude and longitude. Heights and plume-rise parameters for point sources are next, along with the heights for area and line sources. The number of pollutants that are to be included in the calculation is then entered along with the pollutant type, the physical state of the pollutant, and its characteristics. Finally, the source strengths are included for point, area, and line sources, respectively.

Grouping similar data together like this permits the running of several cases with different numbers of sources, pollutants, effective source heights, and emission rates for a particular geographic location and climatology; makes the program flexible; allows the calculation of extended scenarios for long-term effects; and minimizes the internal core storage required by the program because the data can be read in the input data stream, used immediately to perform the needed calculations, and then overwritten as additional data are read in describing the new source strengths.

The input data fields have been kept to either five or ten characters in length. In addition, each format is reused in succeeding input data acquisition statements to reduce the number of required formats.

ENTERING DATA: THE READ AND FORMAT STATEMENTS

All of the READ statements used by ATM to read the data are listed in Table 4 along with the data blocks that they read. The FORMAT statements that these READ statements use are listed below in the descriptions of the data blocks.

Table 4. The READ and FORMAT statements occurring in ATM and the data blocks with which they are associated.

Data Block	READ and FORMAT Statements
1.	READ (IN,99) ATITLE 99 FORMAT (10A8)
2.	READ (IN,97) KDISP, KTAG, KSEA, ROUGH 97 FORMAT (3I5, E10.0)
3.	READ (IN,70)(HTA(I),I=1,KSEA) 70 FORMAT (7E10.3)
4.	READ (IN,700 (HTN(I),I=1,KSEA) 70 FORMAT (7E10.3)
5.	READ (IN,81) NWINDS, NDIR, NFSTAB, (JSTAB(I),I=1,NFSTAB) 81 FORMAT (16I5)

6. READ (IN,70) (WINDS(I),I=1,NWINDS)
70 FORMAT (7E10.3)

7. READ (IN,87) (SEANAM(ISEA),ISEA=1,KSEA)
87 FORMAT (7(2X, A8))

8. READ (IN,86) KDUMMY
86 FORMAT (A4)

9. READ (IN,85) (FREQ(ISEA,I,J,K),J=1,NWINDS)
85 FORMAT (6X, 8F7.4)

10. READ (IN,81) NG, NP, NA, NL, NWS, NBG
81 FORMAT (16I5)

11. READ (IN,78) (SKIPG(I),I=1,NG)
78 FORMAT (16L5)

12. IF (NP.NE.0) READ (IN,78) (SKIPP(I),I=1,NP)
78 FORMAT (16L5)

13. IF (NA.NE.0) READ (IN,78) (SKIPA(I),I=1,NA)
78 FORMAT (16L5)

14. IF (NL.NE.0) READ (IN,78) (SKIPL(I),I=1,NL)
78 FORMAT (16L5)

15. READ (IN,37) GLATD, GLATM, GLATS, GLOND, GLONM, GLONS, HTG(I), GNAME(I)
37 FORMAT (7F10.5, 2X, A8)

16. READ (IN,37) PLATD, PLATM, PLATS, PLOND, PLONM, PLONS, HGT(J), PNAME(J)
37 FORMAT (7F10.5, 2X, A8)

17. READ (IN,37) ALATD, ALATM, ALATS, ALOND, ALONM, ALONS, HGA(K), ANAME(K)
37 FORMAT (7F10.5, 2X, A8)

18. READ (IN,37) LLATDS, LLATMS, LLATSS, LLONDS, LLONMS, LLONSS, HGL(L), LNAME(L)
37 FORMAT (7F10.5, 2X, A8)

19. READ (IN,37) LLATDF, LLATMF, LLATSF, LLONDF, LLONMF, LLONSF
37 FORMAT (7F10.5, 2X, A8)

20. READ (IN,70) (AREA(K),K=1,NA)
70 FORMAT (7E10.3)

21. READ (IN,70) (ST(J),J=1,NP)
70 FORMAT (7E10.3)

22. READ (IN,70) (AT(J),J=1,NP)
70 FORMAT (7E10.3)

23. READ (IN,70) (RAD(J),J=1,NP)
70 FORMAT (7E10.3)

24. READ (IN,70) (VEL(J),J=1,NP)
70 FORMAT (7E10.3)

```
25. READ (IN,61) NPOL, KCOVER
    61 FORMAT (I5, F5.0)
26. READ (IN,78) (SKIPOL(I),I=1,NPOL)
    78 FORMAT (16L5)
27. READ (IN,55) (IPTYPE(M),DF1(M),DF2(M),THALF(M),IPAR(M),
    POLNAM(M),M=1,NPOL)
    55 FORMAT (I5, 3E10.0, I2, 2X, A8)
28. READ (IN,70) (PQI0(I,M,MON),MON=1,KSEA)
    70 FORMAT (7E10.3)
29. READ (IN,70) (AQI0(K,M,MON),MON=1,KSEA)
    70 FORMAT (7E10.3)
30. READ (IN,70) (LQI0(L,M,MON),MON=1,KSEA)
    70 FORMAT (7E10.3)
31. READ (IN,70) (COPT(I,M,MON),MON=1,KSEA)
    70 FORMAT (7E10.3)
32. READ (IN,45) (ITYPE(I),DEN(I),DSALT(I),DSUSP(I),I=1,NWS)
    45 FORMAT (I10, 3E10.0)
33. READ (IN,70) (CONCF(K,M),M=1,NPOL)
    70 FORMAT (7E10.3)
34. READ (IN,70) (FDRY(MON),MON=1,KSEA)
    70 FORMAT (7E10.3)
35. READ (IN,70) (SSCON(I),I=1,NWS)
    70 FORMAT (7E10.3)
36. READ (IN,61) ICHO
    61 FORMAT (I5, F5.0)
```

4.3 INPUT AND OUTPUT

In the following, 36 input data blocks are described, each of which contains data acquired by a single READ statement in the main section of ATM. For each of these data blocks, the format, the input variable names, their units, and their usage are given.

Data Block 1 FORMAT (10A8)

ATITLE = an 80-character name for this particular computer run. This choice of a name is completely left to the user and is simply printed out as a heading at the beginning of the calculation.

Data Block 2 FORMAT (3I5,E10.0)

KDISP = a control variable for the calculation of the sigma dispersion coefficients; it can have a value of 1, 2, or 3:

= 1 indicates that the Pasquill-Gifford stability parameters are to be used.

= 2 indicates that Hosker's formulation of the Briggs-Smith dispersion parameters are to be calculated in subroutine SIGMA and used rather than the Pasquill-Gifford dispersion coefficients.

= 3 indicates that the Briggs dispersion parameters are to be used but without a roughness factor.

KTAG = a control variable for specifying whether or not detailed printout of dispersion parameters and wind rose frequency table is desired.

= 1 produces a detailed printout.

= 2 produces no detailed printout.

KSEA = the number of periods (months or seasons) to be considered in this run; KSEA must be less than or equal to 12 in the current version. The names of these periods will be read in a following READ statement. The number of intervals (months, emissions, etc.) used in the wind frequency tables should be the same as the number used in the source inventories, or the results may be misleading. If the two sets of data are based on different time scales, the source strength should be averaged to the same interval as is used for the wind data.

ROUGH = the roughness parameter for use in the Hosker formulation of dispersion coefficients. This effective roughness parameter is approximately 1/100th of the height of intrusions into the atmosphere (such as trees, towers, and buildings) in meters. A value for ROUGH is only required if KDISP = 2.

Data Block 3 FORMAT (7E10.3)

HTA = a climatological mean value of the afternoon mixing height in meters. Multiple values of HTA are input, one for each period.

Data Block 4 FORMAT (7E10.3)

HTN = a climatological mean value of the nocturnal mixing height in meters. Again, there is one value of HTN for each period.

Data Block 5 FORMAT (16I5)

NWINDS = the number of wind-speed classes included in the following wind-rose frequency table; the number must be no more than eight in the current version.

NDIR = the number of wind directions included in the frequency wind rose. This number should always be 16 in the current version. However, more than or less than 16 wind directions can be used if corresponding modifications are made in subroutine GEOMET.

NFSTAB = the number of stability types included in the wind-rose frequency table. This number typically is six or seven and must be seven or less in the current version. NFSTAB must correspond to the number of stability types assigned in the following array JSTAB. There, the numbers 1 to 7 correspond to Gifford's stability types A to G, respectively.

JSTAB = the Pasquill-Gifford stability type used by the frequency wind rose. For a day-night wind rose, the values of JSTAB should be 1, 2, 3, 4, 4, 5 or 1, 2, 3, 4, 4, 5, 6, as appropriate. The double occurrence of category 4 reflects the division of that class into daytime and nocturnal components. The data from NOAA determines whether five or six classes are represented (sometimes the data from the sixth stability class are included with those for the fifth). The alternative chosen for JSTAB, then, must reflect the form of the wind data read in Data Block 9.

Data Block 6 FORMAT (7E10.3)

WINDSD = the wind speed for each of the wind-speed classes specified by NWINDS. This value is the mean wind speed in meters per second for the wind-rose frequency table.

Data Block 7 FORMAT (7(2X,A8))

SEANAM = an eight-character name for each period, the total number of which is set by the variable KSEA in Data Block 2. There should be one name right-adjusted in each field of ten columns. Seven season names can be accommodated per input data card image. If there are more than seven, another card image identical in format should follow in the input data stream until the total number of periods equals KSEA.

Data Block 8 FORMAT (A4)

KDUMMY = a title card image for the joint frequency table.

Data Block 9 FORMAT (6X,8F7.4)

FREQ = a joint frequency wind rose that takes into consideration direction, wind speed, and stability class with the total number of entries determined by the values of NWINDS, NDIR, and NFSTAB. The array FREQ will be normalized within the main program so the sum of the elements of FREQ for the period ISEA is unity.

Therefore, the input units for this array are arbitrary although the same units must be used for each period ISEA. Each input data card image should contain NWINDS values for the relative occurrence of the wind-speed class for the given wind-stability type and wind direction.

Data Block 10 FORMAT (16I5)

NG = the number of receptor gages (≤ 40) at which the values of deposition and concentration are desired.

NP = the number of point sources (≤ 10) from which pollutants emanate.

NA = the number of area sources (≤ 10) from which emissions occur.

NL = the number of line sources (≤ 10) from which emissions occur.

NWS = the number of windblown sources from which resuspension occurs. The number of windblown sources should be included in the count of total area sources, NA. The number of area sources that are not windblown resuspension sources is equal to the difference between NA and NWS.

NBG = the parameter indicating whether or not background-concentration values are to be input (NBG > 0 indicates that background values are to be read for each pollutant).

Data Block 11 FORMAT (16L5)

If NG is greater than zero (i.e., if there are any gages), the following data must be entered and read individually for each gage.

SKIPG = T if the particular gage is to be skipped during the ensuing calculations.
= F or blank if the calculations are to be performed.

These logical variables are read in fields five characters wide. Sixteen gages can be specified on each card image. The value T must occur within each five-column field if the gage is to be skipped in the ensuing calculations. The value F must be placed anywhere within that five-column field or the field left blank if the calculations are to be performed for that particular receptor gage.

Data Block 12 FORMAT (16L5)

If NP is not equal to zero (i.e., if there are any point sources), the following data must be entered for each point source.

SKIPP	=	T if the particular point source is to be skipped during the ensuing calculations.
	=	F or blank if the calculations are to be performed.

Values are input in the same manner as for SKIPG (Data Block 11).

Data Block 13 FORMAT (16L5)

If NA is not equal to zero (i.e., if there are any area sources), the following data must be entered for each area source.

SKIPA	=	T if the calculations for this area source are to be skipped.
	=	F or blank if the calculations are to be performed.

Values are input in the same manner as for SKIPG (Data Block 11).

Data Block 14 FORMAT (16L5)

If NL is not equal to zero (i.e., if there are any line sources), the following data must be entered for each line source.

SKIPL	=	T if this line source is to be skipped during the ensuing calculations.
	=	F or blank if the calculations are to be performed.

Values are input in the same manner as for SKIPG (Data Block 11).

Data Block 15 FORMAT (7F10.5,2X,A8)

GLATD	=	the degrees of the gage latitude.
GLATM	=	the minutes of the gage latitude.
GLATS	=	the seconds of the gage latitude.
GLOND	=	the degrees of the gage longitude.
GLONM	=	the minutes of the gage longitude.
GLONS	=	the seconds of the gage longitude.
HTG	=	the elevation of the gage relative to a base plane.
GNAME	=	the eight-character name for this receptor gage; it is adjusted to fall in columns 73 to 80. This name is simply printed out as an identification in the following calculations.

Data Block 16 FORMAT (7F10.5,2X,A8)

PLATD	=	the degrees of the point-source latitude.
PLATM	=	the minutes of the point-source latitude.
PLATS	=	the seconds of the point-source latitude.
PLOND	=	the degrees of the point-source longitude.
PLONM	=	the minutes of the point-source longitude.
PLONS	=	the seconds of the point-source longitude.
HGT	=	the height of the point source.

PNAME	=	the eight-character name for this point source adjusted to fall in columns 73 to 80. This name is also printed out in the following calculations.

Data Block 17 FORMAT (7F10.5,2X,A8)

ALATD	=	the degrees of the area-source latitude.
ALATM	=	the minutes of the area-source latitude.
ALATS	=	the seconds of the area-source latitude.
ALOND	=	the degrees of the area-source longitude.
ALONM	=	the minutes of the area-source longitude.
ALONS	=	the seconds of the area-source longitude.
HGA	=	the height of the area source.
ANAME	=	the eight-character name for this area source adjusted to fall in columns 73 to 80. This area-source name is also printed out in the following calculations.

Data Block 18 FORMAT (7F10.5,2X,A8)

LLATDS	=	the degrees of the line source's starting-point latitude.
LLATMS	=	the minutes of the line source's starting-point latitude.
LLATSS	=	the seconds of the line source's starting-point latitude.
LLONDS	=	the degrees of the line source's starting-point longitude.
LLONMS	=	the minutes of the line source's starting-point longitude.
LLONSS	=	the seconds of the line source's starting-point longitude.
HGL	=	the height of the line source.
LLNAME	=	the eight-character name for this line source adjusted to fall in columns 73 to 80. This name is also be printed out for identification in the following calculations.

Data Block 19 FORMAT (7F10.5,2X,A8)

LLATDF	=	the degrees of the line source's ending-point latitude.
LLATMF	=	the minutes of the line source's ending-point latitude.
LLATSF	=	the seconds of the line source's ending-point latitude.
LLONDF	=	the degrees of the line source's ending-point longitude.
LLONMF	=	the minutes of the line source's ending-point longitude.
LLONSF	=	the seconds of the line source's ending-point longitude.

Note that there is no name attached to the ending point of a line source; the ending point has the same name that is attached to its starting point. A name can be inserted in this field; however, that name will not be printed out in the following calculations.

Data Block 20 FORMAT (7E10.3)

AREA	=	the area of an area source in square meters. Seven such areas are read per card image, and the data should continue on the next card image if there are more than seven area sources. The maximum number of area sources allowed in the current program is ten.

Data Block 21 FORMAT (7E10.3)

ST = the temperature in degrees Kelvin at the exit port of each point source (stack or vent).

Data Block 22 FORMAT (7E10.3)

AT = the ambient temperature in degrees Kelvin near each point source.

Data Block 23 FORMAT (7E10.3)

RAD = the radius in meters of the exit port for each point source.

Data Block 24 FORMAT (7E10.3)

VEL = the exit velocity in meters per second of the effluent from each point source.

Data Block 25 FORMAT (I5,F5.0)

NPOL = the number of pollutants for which the following calculations are to be performed.

KCOVER = the cover-type specification, which is generally between 1.0 and 10.0. This cover specification enhances the deposition velocity, which is assumed to be 0.01 m/sec for all pollutants. This parameter is basically related to the type of vegetation that covers the area being modeled. A value of 1.0 is appropriate for grassland, and a value of 10.0 is appropriate for dense forest. KCOVER can be set to 0.0 if appropriate.

Data Block 26 FORMAT (16L5)

SKIPOL = a logical variable that specifies whether or not each pollutant is to be skipped in the following calcultions.
= T skips the calculations for this particular pollutant.
= F or blank performs the calculations for this pollutant.

Data Block 27 FORMAT (I5,3E10.0,I2,2X,A8)

IPTYPE = the pollutant type, particulate or gas.
= 1 implies the pollutant is a particulate.
= 2 implies the pollutant is a gas.

DF1 = the diameter of the particle in 10^{-6}m if IPTYPE = 1. DF1 is not used if IPTYPE = 2.

DF2 = the density of the particle in g/cm^3 if IPTYPE = 1 or the diffusivity of the gas in air in m^2/s if IPTYPE = 2.

THALF = the half-life for pollutant reaction or decay in seconds; the default value is 10^{12} sec if this field is left blank.

IPAR = the parameter that labels the pollutant as a "daughter" of another pollutant. The value of IPAR indicates the parent of the pollutant.

POLNAM = the eight-character name for the pollutant of interest; this name is simply printed out as an identification during the remainder of the calculations.

Data Block 28 FORMAT (7E10.3)

PQI0 = the pollutant source strength in grams per second of the first pollutant from the first point source. One value is entered for each period covered by the calculations. Seven such source strengths can be entered on each card image; additional data can be entered on additional card images until KSEA (the number of periods) values are entered. Similar data are then entered for the next pollutant (starting in columns 1 through 10 of a new card image). A series of such card images must be entered for each pollutant emanating from the first source. Once the pollutants from one source are thus characterized, the pollutants from the next source are described in a like manner. This process is repeated until the emissions from all the point sources are quantified.

Data Block 29 FORMAT (7E10.3)

AQI0 = area source strength in grams per square meter per second of the first pollutant from the first area source. One value is entered for each period covered by the calculations. Seven such source strengths can be entered on each card image; additional data can be entered on additional card images until KSEA (the number of periods) values are entered. Similar data are then entered for the next pollutant (starting in columns 1 through 10 of a new card image). A series of such card images must be entered for each pollutant emanating from the first source. Once the pollutants from one source are thus characterized, the pollutants from the next source are described in a like manner. This process is repeated until the emissions from all the area sources are quantified.

Data Block 30 FORMAT (7E10.3)

LQI0 = the line source strength in grams per meter of the first pollutant from the first line source. One value is entered for each period covered by the calculations. Seven such source strengths can be entered on each card image; additional data can be entered on additional card images until KSEA (the number of periods) values are entered. Similar data are then entered for the next pollutant (starting in columns 1 through 10 of a new card image). A series of such card images must be entered for each pollutant emanating from the first source. Once the pollutants from one source are thus characterized, the pollutants from the next source are described in a like manner. This process is repeated until the emissions from all the line sources are quantified.

Data Block 31 FORMAT (7E10.3)

COPT = the background concentration in grams per cubic meter for each pollutant for each gage (read only if NBG is not zero).

Data Block 32 FORMAT (I10,3E10.0)

One set of the following data is entered for each windblown source.

ITYPE = 1 for nearly uniform, fine sand.
= 2 for sand with a grain-size distribution similar to that of sand that occurs in nature.
= 3 for wide ranges in grain sizes.

DEN = the density of the grain in grams per cubic meter.

DSALT = the saltation diameter in meters.

DSUSP = the suspension diameter in meters.

Data Block 33 FORMAT (7E10.3)

CONCF = the fraction of the total concentration of the windblown source that is pollutant. Seven such fractions can be entered on each card image.

Data Block 34 FORMAT (7E10.3)

FDRY = the fraction of time the source remains dry during each period. Seven such fractions can be entered on each card image.

Data Block 35 FORMAT (7E10.3)

SSCON = the suspension-to-saltation ratio for the source in reciprocal meters. Seven such periods can be entered on each card image.

Data Block 36 FORMAT (I5)

ICHO = a control parameter that indicates whether monthly-average climatological results or episodic results are to be calculated.
= 1 indicates that monthly-average climatological calculations are to be performed by calling the subroutine DCAL.
= 2 indicates that episodic calculations are to be performed for all the stability classes and periods of interest by calling the subroutine MAXCON.

This version of ATM is dimensioned to accept input data for as many as 40 gages (receptor points) at one time. To compute concentrations at more than 40 locations, Data Blocks 10, 11, and 15 for each new set of 40 gages or fraction thereof can be repeated following Data Block 36. Runs of 320 points have been made routinely at ORNL to prepare concentration isopleths.

This summary of the input data read by ATM should provide sufficient information for the user to produce a corresponding data set applicable to a specific problem. To illustrate the structure of a data set, data are presented in Appendix C of this report for a sample calculation with this model. Note that much of the input data defines the frequency table FREQ for the stability windrose for a single period. Since one will have 80, 96, or 112 card images for each period of interest, data sets can be quite large.

The output from ATM when the sample data is used is given in Appendix F. A more detailed output could have been produced by setting KTAG in Data Block 2 to 1. With that setting, some of the input data will be output. The user will probably wish to exercise this option the first time a new data set is used.

The more detailed output includes the following: a table of the Briggs-Smith dispersion values out to 100 km, the stability wind-rose data for each period, the distance and direction from each source to each receptor gage, the angular spread from each gage to each area source, and the sector fractions for each gage and each area source.

The output always includes the following: the type of dispersion values used; the type of wind data; the number of periods; the location and height of the gages; the location, height, and output of all sources; the stack characteristics for point sources; the wind speeds as functions of height; the sizes of area sources (square meters) and line sources (meters); the afternoon and nocturnal mixing heights; data for each pollutant; the contribution of each type of source (point, area, and line) to concentration and deposition; and the integrated deposition (both wet and dry) and concentration at each gage for all the sources. This last output is listed separately for each pollutant and period.

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APPENDIX A

LIST OF SYMBOLS

APPENDIX A

LIST OF SYMBOLS

C	sand uniformity constant
d	grain diameter (cm)
D	standard grain diameter (cm)
f	settling velocity of dust particle (m/s)
F_B	buoyancy flux (m^4/s^3)
F_d	fraction of time windblown source remains dry
$F_{pr}(\theta)$	fraction of the time the wind blows from direction θ, with wind speed class r, and stability class p
g	gravitational acceleration (m/s^2)
h	effective stack height (m)
h_o	actual stack height (m)
k	surface roughness during saltation (cm)
K_x, K_y	eddy diffusivities (m^2/s)
n_p	stability power law parameter
p	stability index
q	volume concentration of particulates (g/m^3)
Q	effective source strength (g/s)
r	stack radius (m)
R	distance from receptor gage to area source centroid (m)
R_f	suspension to saltation ratio (m^{-1})
R_1	distance from receptor gage to nearest boundary of polar area source (m)
R_2	distance from receptor gage to farthest boundary of polar area source (m)
s	temperature profile parameter (s^{-2})
t	time (s)
T_E	air temperature (K)
T_S	stack-gas temperature (K)
u	wind speed in the x-direction (m/s)
u_t	threshold wind speed for saltation (m/s)
v	deposition velocity (m/s)
W	stack ejection velocity (m/s)
W_f	fraction of time only dry deposition occurs
W_w	fraction of time both wet and dry deposition occur
x	distance downwind from source (m)
x^*	cutoff distance downwind for plume rise (m)
y	distance crosswind from the plume axis (m)
z	vertical distance from ground (m)
Δh	plume rise (m)
$\Delta\theta$	angular spread of polar area source (radians) as seen from a receptor gage
θ	one of sixteen principal compass directions clockwise from north
λ	washout coefficient (s^{-1})
σ_y, σ_z	horizontal and vertical dispersion (m)
χ	ground-level air concentration (g/m^3)
ω	deposition rate (g/m^2-s)

APPENDIX B

PROGRAM LISTING

```
C          MAIN PROGRAM ATM (AIR TRANSPORT MODEL)
C ***  THIS VERSION IS SET UP TO RUN MORE THAN 40 GAGES,10 POINT
C *** SOURCES, 10 AREA SOURCES, 10 LINE SOURCES, AND 20 POLLUTANTS.
      LOGICAL SKIPP, SKIPA, SKIPL, SKIPG, SKIPOL
      REAL LSTHA, LFTHA, LSPHI, LFPHI
      REAL LLATDS, LLATMS, LLATSS
      REAL LLATDF, LLATMF, LLATSF
      REAL LLONDS, LLONMS, LLONSS
      REAL LLONDF, LLONMF, LLONSF
      REAL LQIO, KCOVER
      DOUBLE PRECISION ATITLE, SEANAM, GNAME, PNAME, ANAME, LNAME,
     *     POLNAM
      COMMON /C1/ XM(50), SIGTAB(6,50), SIGMAX(6), V(20), DV(20),
     *     CLAMDA(20), DLAMDA(40,12,20), NDIST, NSTAB
      COMMON /C2/ H
      COMMON /C3/ PI, R, KOUT
      COMMON /C4/ DP(40,10), DA(40,10), DIRP(40,10), DIRA(40,10),
     *     AREA(10)
      COMMON /C5/ DTH(40,10), R1(40,10), R2(40,10), TH1(40,10),
     *     TH2(40,10)
      COMMON /C6/ FREQ(12,7,8,16), HGT(10), PQIO(10,20,12), IPAR(20),
     *     AQIO(10,20,12), LQIO(10,20,12), THALF(20), HMIX(8,12)
      COMMON /C8/ NG, NP, NA, NL, NWS, NPOL, NFSTAB, NWINDS, WW, WF,
     *     FDRY(12)
      COMMON /C9/ COPT(40,20,12), HTG(40)
      COMMON /C10/ LSTHA(10), LFTHA(10), LSPHI(10), LFPHI(10)
      COMMON /C11/ GTHA(40), GPHI(40), PTHA(10), PPHI(10), ATHA(10),
     *     APHI(10)
      COMMON /C12/ WQIO(3,5,8), VFALL(3)
      COMMON /C13/ HGA(10), HGL(10)
      COMMON /C14/ KDISP, KCOVER, ROUGH
      COMMON /C15/ SKIPP(10), SKIPA(10), SKIPL(10), SKIPG(40),
     *     SKIPOL(20)
      COMMON /C16/ KSEA
      COMMON /C18/ ATITLE(10), SEANAM(12), GNAME(40), PNAME(10),
     *     ANAME(10), LNAME(10), POLNAM(20), COMP(32), F(32,40,10)
      COMMON /C19/ CONCF(3,5), SSCON(3), DEN(3), DSALT(3), DSUSP(3),
     *     ITYPE(3)
      COMMON /C20/ ST(10), AT(10), RAD(10), VEL(10), PKAPPA(10),
     *     QKAPPA(10)
      DIMENSION FRACT(12), AVRATE(12), GRATE(40,12), GFRACT(40,12)
      DIMENSION IPTYPE(20), DF1(20), DF2(20), JSTAB(7), WINDSD(8,7,10)
      DIMENSION PURBAN(7), PRURAL(7), WINDS(8), HTA(12), HTN(12)
      DATA PURBAN /0.1,0.15,0.2,0.25,0.25,0.3/
C     DATA PURBAN /0.15,0.15,0.20,0.25,0.40,0.60,0.60/
      DATA PRURAL /0.07,0.07,0.10,0.15,0.35,0.55,0.55/
C ***  NPOL=NUMBER OF POLLUTANTS
C ***  R=EARTH'S RADIUS IN METERS, NG=NUMBER OF RAIN GAUGES, NP=NUMBER
C ***  OF POINT SOURCES, NA=NUMBER OF AREA SOURCES, (GLATD,GLATM,GLATS)
C ***  =LATITUDE OF RAIN GAUGE IN DEGREES,MINUTES,AND SECONDS. (GLOND,
C ***  GLONM,GLONS)=LONGITUDE OF RAIN GAUGE IN DEGREES,MINUTES,AND
C ***  SECONDS.(PLATD,PLATM,PLATS)=LATITUDE OF POINT SOURCE IN DEGREES,
C ***  MINUTES,AND SECONDS, (PLOND,PLONM,PLONS)=LONGITUDE OF POINT
C ***  SOURCE IN DEGREES,MINUTES,AND SECONDS. (ALATD,ALATM,ALATS)=
C ***  LATITUDE OF CENTROID OF AREA SOURCE IN DEGREES,MINUTES,
C ***  AND SECONDS (ALOND,ALONM,ALONS)=LONGITUDE OF CENTROID OF AREA
C ***  SOURCE IN DEGREES, MINUTES,AND SECONDS
C ***  DP(I,J)=DISTANCE IN METERS FROM GAUGE I TO POINT SOURCE J
C ***  DA(I,K)=DISTANCE IN METERS FROM GAUGE I TO CENTROID OF AREA
C ***  SOURCE K, DIRP(I,J)=DIRECTION IN DEGREES FROM GAUGE I TO POINT
C ***  SOURCE J(MEASURED CLOCKWISE FROM DUE NORTH)
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C ***  DIRA(I,K)=DIRECTION IN DEGREES FROM GAUGE I TO CENTROID OF AREA
C ***  SOURCE K(MEASURED CLOCKWISE FROM NORTH)
C ***  AREA(K)=AREA OF AREA SOURCE K IN METERS**2
C ***  (LLATDS,LLATMS,LLATSS)=LATITUDE OF THE STARTING POINT OF THE
C ***  LINE SOURCE IN DEGREES,MINUTES,AND SECONDS
C ***  (LLONDS,LLONMS,LLONSS)=LONGITUDE OF THE STARTING POINT OF THE
C ***  LINE SOURCE IN DEGREES,MINUTES,AND SECONDS
C ***  (LLATDF,LLATMF,LLATSF)=LATITUDE OF THE TERMINATION POINT OF THE
C ***  LINE SOURCE IN DEGREES,MINUTES,AND SECONDS
C ***  (LLONDF,LLONMF,LLONSF)=LONGITUDE OF THE TERMINATION POINT OF
C ***  THE LINE SOURCE IN DEGREES,MINUTES,AND SECONDS
C ***  IPTYPE(M)=1, POLLUTANT M IS A PARTICULATE
C ***  IPTYPE(M)=2, POLLUTANT M IS A GAS
C ***  AND PARTICLE SIZE DATA
      IN = 5
      KOUT = 6
      ISWICH = 0
      R = 6.378E+6
      PI = 3.1415927
      PI180 = PI/180.0
C ***  NA=NUMBER OF AREA SOURCES(INCLUDING WINDBLOWN AREA SOURCES)
C ***  NWS=NUMBER OF WINDBLOWN AREA SOURCES
C ***  DATA FOR WINDBLOWN SOURCES LISTED AFTER THAT FOR THE
C ***  ORDINARY AREA SOURCES
C ***  IN OTHER WORDS, IF YOU HAVE 4 AREA SOURCES, 2 OF WHICH
C ***  ARE WINDBLOWN, AREA SOURCES 1 AND 2 WILL BE ORDINARY
C ***  AND 3 AND 4 WILL BE WINDBLOWN
      READ (IN,99) ATITLE
      WRITE (KOUT,98) ATITLE
C ***  NDIST=NUMBER OF DISTANCES IN THE STABILITY TABLE
C ***  NSTAB=NUMBER OF STABILITIES IN THE TABLE
C ***  SIGTAB=VARIOUS PASQUILL STABILITIES
C ***  KDISP=1, USE PASQUILL STABILITY TABLE
C ***  KDISP=2, USE SMITH'S STABILITY FORMULATION WITH MODIFICATION
C ***            DUE TO SURFACE ROUGHNESS(SEE R.P. HOSKER'S PAPER)
C ***  KDISP=3, USE BRIGGS STABILITIES(SEE GIFFORD'S PAPER IN
C ***  NUCLEAR SAFETY)
C ***  KCOVER<5  GRASS COVER
C ***  KCOVER>5  FOREST COVER
C ***  ROUGH= ROUGHNESS OF THE LAND SURFACE(METERS)
      READ (IN,97) KDISP, KTAG, KSEA, ROUGH
C ***  KTAG=1 WILL PRINT DATA ON WIND DIRECTION FREQUENCY
C ***  TABLES,AREA AND LINE SOURCE PARAMETERS.ONCE RUN ,THESE
C ***  MAY BE BYPASSED BY KTAG=2
C ***  HTA=CLIMATOLOGICAL MEAN VALUE OF AFTERNOON MIXING HEIGHT
C ***  HTN=NOCTURNAL MIXING HEIGHT
      READ (IN,99970) (HTA(I),I=1,KSEA)
      READ (IN,99970) (HTN(I),I=1,KSEA)
C ***  CALCULATE MIXING HEIGHT FOR EACH STABILITY CLASS
C ***  4= D(DAYTIME), 5=D(NIGHTTIME)
      DO 100 J=1,KSEA
        HMIX(1,J) = 1.5*HTA(J)
        HMIX(2,J) = HTA(J)
        HMIX(3,J) = HTA(J)
        HMIX(4,J) = HTA(J)
        HMIX(5,J) = (HTA(J)+HTN(J))*0.5
        HMIX(6,J) = HTN(J)
        HMIX(7,J) = HTN(J)
        HMIX(8,J) = HTN(J)
  100 CONTINUE
```

```
      IF (KDISP.GT.1) GO TO 200
      WRITE (KOUT,96)
      GO TO 700
  200 WRITE (KOUT,95)
      IF (KDISP.EQ.3) GO TO 300
      WRITE (KOUT,94)
      GO TO 400
  300 WRITE (KOUT,93)
  400 DO 600 IP=1,NSTAB
        DO 500 I=1,NDIST
          SIGTAB(IP,I) = SIGMA(IP,XM(I),IDUM,ADUM)
  500   CONTINUE
  600 CONTINUE
  700 IF (KTAG.EQ.2) GO TO 800
      WRITE (KOUT,92)
      WRITE (KOUT,91) (XM(I),(SIGTAB(IP,I),IP=1,NSTAB),I=1,NDIST)
  800 IF (KDISP.NE.2) GO TO 900
      WRITE (KOUT,90) ROUGH
C ***  NWINDS=NUMBER OF WIND SPEEDS IN THE FREQUENCY TABLE
C ***  NDIR=NUMBER OF DIRECTIONS IN THE FREQUENCY TABLE
C ***  NFSTAB=NUMBER OF WIND STABILITIES IN THE FREQUENCY TABLE
C ***  JSTAB(I)=INDEX OF STABILITIES TO BE USED
  900 READ (IN,81) NWINDS, NDIR, NFSTAB, (JSTAB(I),I=1,NFSTAB)
      WRITE (KOUT,89) NWINDS, NDIR, NFSTAB, (JSTAB(I),I=1,NFSTAB)
C ***  SIGMAX(IP)=MAXIMUM VALUE OF VERTICAL DISPERSION FOR EACH
C STABILITY
      WRITE (KOUT,88) (SIGMAX(IP),IP=1,NSTAB)
C ***  WINDS(I)=WIND SPEED IN METERS/SEC FOR WIND SPEED CLASS I
      READ (IN,70) (WINDS(I),I=1,NWINDS)
C ***    KSEA=NUMBER OF MONTHS OF DATA FOR WIND ROSE
      READ (IN,87) (SEANAM(ISEA),ISEA=1,KSEA)
      READ (IN,86) KDUMMY
      DO 1600 ISEA=1,KSEA
        SUM = 0.0
        DO 1200 I=1,NFSTAB
          DO 1100 K=1,NDIR
            READ (IN,85) (FREQ(ISEA,I,J,K),J=1,NWINDS)
            DO 1000 J=1,NWINDS
              SUM = SUM + FREQ(ISEA,I,J,K)
 1000       CONTINUE
 1100     CONTINUE
 1200   CONTINUE
        DO 1500 I=1,NFSTAB
          DO 1400 K=1,NDIR
            DO 1300 J=1,NWINDS
              FREQ(ISEA,I,J,K) = FREQ(ISEA,I,J,K)/SUM
 1300       CONTINUE
 1400     CONTINUE
 1500   CONTINUE
 1600 CONTINUE
      IF (KTAG.EQ.2) GO TO 2000
      DO 1900 ISEA=1,KSEA
        WRITE (KOUT,84) ISEA, SEANAM(ISEA)
        DO 1800 I=1,NFSTAB
          WRITE (KOUT,83) JSTAB(I)
          DO 1700 K=1,NDIR
            WRITE (KOUT,82) K, (FREQ(ISEA,I,J,K),J=1,NWINDS)
 1700     CONTINUE
 1800   CONTINUE
 1900 CONTINUE
```

```
 2000 READ (IN,81) NG, NP, NA, NL, NWS, NBG
      IF (NG.EQ.0) GO TO 2100
      IF (NP.NE.0) GO TO 2200
      IF (NA.NE.0) GO TO 2200
      IF (NL.NE.0) GO TO 2200
      WRITE (KOUT,80)
      STOP
 2100 WRITE (KOUT,79)
      STOP
C ***    SKIPG(I)=T  GAUGE I NOT USED,  =F USED
C ***    SKIPP(I)=T POINT SOURCE I NOT USED, =F USED
C ***    SKIPA(I)=T AREA SOURCE I NOT USED, =F USED
C ***    SKIPL(I)=T LINE SOURCE I NOT USED, =F USED
 2200 READ (IN,78) (SKIPG(I),I=1,NG)
      IF (NP.NE.0) READ (IN,78) (SKIPP(I),I=1,NP)
      IF (NA.NE.0) READ (IN,78) (SKIPA(I),I=1,NA)
      IF (NL.NE.0) READ (IN,78) (SKIPL(I),I=1,NL)
 2300 ISWICH = ISWICH + 1
      IF (ISWICH.EQ.1) GO TO 2400
      READ(IN,81,END=8000)  NG
      READ (IN,78) (SKIPG(I),I=1,NG)
 2400 CONTINUE
      WRITE (KOUT,77)
      WRITE (KOUT,36)
      DO 2500 I=1,NG
        READ (IN,37) GLATD, GLATM, GLATS, GLOND, GLONM, GLONS,
     *       HTG(I), GNAME(I)
        IF (SKIPG(I)) GO TO 2500
        WRITE (KOUT,75) I, GNAME(I), GLATD, GLATM, GLATS, GLOND,
     *       GLONM, GLONS, HTG(I)
        GTHA(I) = PI180*(GLATD+(GLATM+GLATS/60.0)/60.0)
        GPHI(I) = PI180*(GLOND+(GLONM+GLONS/60.0)/60.0)
 2500 CONTINUE
      IF (ISWICH.GT.1) CALL GEOMET(KTAG)
      IF (ISWICH.GT.1) GO TO 6100
      IF (NP.EQ.0) GO TO 2700
      WRITE (KOUT,74)
      WRITE (KOUT,76)
C ***  HGT(I)=HEIGHT OF POINT SOURCE I
C ***  HGA(K)=HEIGHT OF AREA SOURCE K
C ***  HGL(L)=HEIGHT OF LINE SOURCE L
      DO 2600 J=1,NP
        READ (IN,37) PLATD, PLATM, PLATS, PLOND, PLONM, PLONS,
     *       HGT(J), PNAME(J)
        IF (SKIPP(J)) GO TO 2600
        WRITE (KOUT,75) J, PNAME(J), PLATD, PLATM, PLATS, PLOND,
     *       PLONM, PLONS
        PTHA(J) = PI180*(PLATD+(PLATM+PLATS/60.0)/60.0)
        PPHI(J) = PI180*(PLOND+(PLONM+PLONS/60.0)/60.0)
 2600 CONTINUE
 2700 IF (NA.EQ.0) GO TO 2900
      WRITE (KOUT,73)
      WRITE (KOUT,76)
      DO 2800 K=1,NA
        READ (IN,37) ALATD, ALATM, ALATS, ALOND, ALONM, ALONS,
     *       HGA(K), ANAME(K)
        IF (SKIPA(K)) GO TO 2800
        WRITE (KOUT,75) K, ANAME(K), ALATD, ALATM, ALATS, ALOND,
     *       ALONM, ALONS, HGA(K)
        ATHA(K) = PI180*(ALATD+(ALATM+ALATS/60.0)/60.0)
        APHI(K) = PI180*(ALOND+(ALONM+ALONS/60.0)/60.0)
 2800 CONTINUE
```

```
2900 IF (NL.EQ.0) GO TO 3100
     WRITE (KOUT,72)
     WRITE (KOUT,76)
     DO 3000 L=1,NL
       READ (IN,37) LLATDS, LLATMS, LLATSS, LLONDS, LLONMS,
    *        LLONSS, HGL(L), LNAME(L)
       READ (IN,37) LLATDF, LLATMF, LLATSF, LLONDF, LLONMF, LLONSF
       IF (SKIPL(L)) GO TO 3000
       WRITE (KOUT,75) L, LNAME(L), LLATDS, LLATMS, LLATSS,
    *        LLONDS, LLONMS, LLONSS, HGL(L)
       WRITE (KOUT,75) L, LNAME(L), LLATDF, LLATMF, LLATSF,
    *        LLONDF, LLONMF, LLONSF
       LSTHA(L) = PI180*(LLATDS+(LLATMS+LLATSS/60.0)/60.0)
       LFTHA(L) = PI180*(LLATDF+(LLATMF+LLATSF/60.0)/60.0)
       LSPHI(L) = PI180*(LLONDS+(LLONMS+LLONSS/60.0)/60.0)
       LFPHI(L) = PI180*(LLONDF+(LLONMF+LLONSF/60.0)/60.0)
3000 CONTINUE
3100 WRITE (KOUT,71)
     IF (NA.LE.0) GO TO 3300
     READ (IN,70) (AREA(K),K=1,NA)
     WRITE (KOUT,69)
     DO 3200 K=1,NA
       IF (SKIPA(K)) GO TO 3200
       WRITE (KOUT,68) K, ANAME(K), AREA(K)
3200 CONTINUE
3300 CALL GEOMET(KTAG)
C ***  HEIGHT=HEIGHT AT WHICH WIND SPEED IS MEASURED (METERS)
     HEIGHT = 10.
     DIV = 1.0/HEIGHT
     WRITE (KOUT,64) HEIGHT, (WINDS(M),M=1,NWINDS)
     IF (NP.EQ.0) GO TO 4000
C ***  PKAPPA(J)=PLUME RISE PARAMETER IN THE EFFECTIVE SOURCE
C ***  CALCULATION FOR EACH POINT SOURCE FOR STABILITIES 1,2,3,4
C ***  QKAPPA(J)=PLUME RISE PARAMETER IN THE EFFECTIVE SOURCE
C ***  CALCULATION FOR EACH POINT SOURCE FOR STABILITIES 5,6
C ***  THIS PROGRAM WAS CHANGED TO ALLOW SUBROUTINE PLUME
C ***  TO CALCULATE PKAPPA AND QKAPPA.
C ***  ST=STACK GAS TEMP(K), AT=AIR TEMP(K)
C ***  RAD=RADIUS OF STACK(M), VEL=STACK GAS EJECTION VEL(M/SEC)
     READ (IN,70) (ST(J),J=1,NP)
     READ (IN,70) (AT(J),J=1,NP)
     READ (IN,70) (RAD(J),J=1,NP)
     READ (IN,70) (VEL(J),J=1,NP)
     CALL PLUME(NP)
     WRITE (KOUT,67)
     WRITE (KOUT,66)
     DO 3700 I=1,NP
       IF (SKIPP(I)) GO TO 3700
       WRITE (KOUT,65) I, PNAME(I), HGT(I), AT(I), ST(I), RAD(I),
    *        VEL(I)
       DO 3600 J=1,NFSTAB
         DO 3500 K=1,NWINDS
           IF (KDISP.EQ.1) GO TO 3400
           WINDSD(K,J,I) = WINDS(K)*(DIV*HGT(I))**PRURAL(J)
           GO TO 3500
3400       WINDSD(K,J,I) = WINDS(K)*(DIV*HGT(I))**PURBAN(J)
3500     CONTINUE
3600   CONTINUE
3700 CONTINUE
     DO 3900 I=1,NP
       IF (SKIPP(I)) GO TO 3900
       WRITE (KOUT,63) I
```

```
        DO 3800 J=1,NFSTAB
          WRITE (KOUT,62) J, (WINDSD(L,J,I),L=1,NWINDS)
 3800   CONTINUE
 3900 CONTINUE
 4000 CONTINUE
      READ (IN,61) NPOL, KCOVER
      IF (KCOVER.GT.5.0) GO TO 4100
      WRITE (KOUT,60) KCOVER
      GO TO 4200
 4100 WRITE (KOUT,59) KCOVER
 4200 CONTINUE
      WRITE (KOUT,58) (HTA(I),I=1,KSEA)
      WRITE (KOUT,57) (HTN(I),I=1,KSEA)
      IF (NPOL.GT.0) GO TO 4300
      WRITE (KOUT,56)
      STOP
C ***   SKIPOL(I)=T POLLUTANT I NOT USED, =F USED
 4300 READ (IN,78) (SKIPOL(I),I=1,NPOL)
      READ (IN,55) (IPTYPE(M),DF1(M),DF2(M),THALF(M),IPAR(M),
     *     POLNAM(M),M=1,NPOL)
      WRITE (KOUT,67)
      DO 4600 M=1,NPOL
        IF (THALF(M).EQ.0.0) THALF(M) = 1.0E12
        IF (IPAR(M).EQ.0) IPAR(M) = M
        IF (IPTYPE(M).EQ.2) GO TO 4400
        WRITE (KOUT,54) M, POLNAM(M), DF1(M), DF2(M), THALF(M)
        GO TO 4500
 4400   WRITE (KOUT,53) M, POLNAM(M), DF1(M), DF2(M), THALF(M)
 4500   IF (IPAR(M).NE.M) WRITE (KOUT,40) M, IPAR(M)
 4600 CONTINUE
C ***  PQI0(I,M,MON)=EMISSION RATE OF POLLUTANT M DURING MONTH MON FROM
C ***  POINT SOURCE I IN GRAMS/SEC
      IF (NP.EQ.0) GO TO 5100
      DO 4800 I=1,NP
        DO 4700 M=1,NPOL
          READ (IN,70) (PQI0(I,M,MON),MON=1,KSEA)
 4700   CONTINUE
 4800 CONTINUE
      WRITE (KOUT,67)
      WRITE (KOUT,52) (MON,SEANAM(MON),MON=1,KSEA)
      DO 5000 I=1,NP
        IF (SKIPP(I)) GO TO 5000
        DO 4900 M=1,NPOL
          IF (SKIPOL(M)) GO TO 4900
          WRITE (KOUT,51) I, M, (PQI0(I,M,MON),MON=1,KSEA)
 4900   CONTINUE
 5000 CONTINUE
C ***  AQI0(K,M,MON)=EMISSION RATE OF POLLUTANT M DURING MONTH MON FROM
C ***  AREA SOURCE K IN GRAMS/METER**2/SEC
 5100 IF (NA.EQ.0) GO TO 5600
      NAP = NA - NWS
      DO 5300 K=1,NAP
        DO 5200 M=1,NPOL
          READ (IN,70) (AQI0(K,M,MON),MON=1,KSEA)
 5200   CONTINUE
 5300 CONTINUE
      WRITE (KOUT,50) (MON,SEANAM(MON),MON=1,KSEA)
      DO 5500 K=1,NAP
        IF (SKIPA(K)) GO TO 5500
        DO 5400 M=1,NPOL
          IF (SKIPOL(M)) GO TO 5400
          WRITE (KOUT,49) K, M, (AQI0(K,M,MON),MON=1,KSEA)
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 5400   CONTINUE
 5500 CONTINUE
C ***  LQIO(L,M,MON)=EMISSION RATE OF POLLUTANT M DURING MONTH MON FROM
C ***  LINE SOURCE L IN GRAMS/METER/SEC
 5600 IF (NL.EQ.0) GO TO 6100
      DO 5800 L=1,NL
        DO 5700 M=1,NPOL
          READ (IN,70) (LQIO(L,M,MON),MON=1,KSEA)
 5700   CONTINUE
 5800 CONTINUE
      WRITE (KOUT,67)
      WRITE (KOUT,48) (MON,SEANAM(MON),MON=1,KSEA)
      DO 6000 L=1,NL
        IF (SKIPL(L)) GO TO 6000
        DO 5900 M=1,NPOL
          IF (SKIPOL(M)) GO TO 5900
          WRITE (KOUT,47) L, M, (LQIO(L,M,MON),MON=1,KSEA)
 5900   CONTINUE
 6000 CONTINUE
 6100 IF (NBG.EQ.0) GO TO 6700
      DO 6300 I=1,NG
        DO 6200 M=1,NPOL
          READ (IN,70) (COPT(I,M,MON),MON=1,KSEA)
 6200   CONTINUE
 6300 CONTINUE
      WRITE (KOUT,67)
      WRITE (KOUT,39) (MON,SEANAM(MON),MON=1,KSEA)
      DO 6600 I=1,NG
        IF (SKIPG(I)) GO TO 6600
        DO 6500 M=1,NPOL
          IF (SKIPOL(M)) GO TO 6400
          TEST = 0.0
          DO 6400 J=1,KSEA
            IF (COPT(I,M,J).GT.0.0) TEST = COPT(I,M,J)
 6400     CONTINUE
          IF (TEST.EQ.0.0) GO TO 6500
          WRITE (KOUT,38) I, M, (COPT(I,M,MON),MON=1,KSEA)
 6500   CONTINUE
 6600 CONTINUE
      GO TO 7100
C ***  CONCENTRATIONS ARE SET TO 0 IF NO BG VALUES ARE GIVEN
 6700 DO 7000 I=1,NG
        DO 6900 M=1,NPOL
          DO 6800 MON=1,KSEA
            COPT(I,M,MON) = 0.0
 6800     CONTINUE
 6900   CONTINUE
 7000 CONTINUE
 7100 DO 7300 I=1,NG
        CALL FRXTRN(FRACT, AVRATE, KSEA)
        DO 7200 MON=1,KSEA
          GRATE(I,MON) = AVRATE(MON)
          GFRACT(I,MON) = FRACT(MON)
 7200   CONTINUE
 7300 CONTINUE
      IF (ISWICH.GT.1) GO TO 7700
      IF (NWS.EQ.0) GO TO 7600
      WRITE (KOUT,71)
      DO 7400 N=1,NWS
        NN = NA - NWS + N
        WRITE (KOUT,46) NN, N, ANAME(NN)
 7400 CONTINUE
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      READ (IN,45) (ITYPE(I),DEN(I),DSALT(I),DSUSP(I),I=1,NWS)
      WRITE (KOUT,44) (I,ITYPE(I),DEN(I),DSALT(I),DSUSP(I),I=1,NWS)
      DO 7500 K=1,NWS
        READ (IN,70) (CONCF(K,M),M=1,NPOL)
        WRITE (KOUT,43) K, (M,CONCF(K,M),M=1,NPOL)
 7500 CONTINUE
      READ (IN,70) (FDRY(MON),MON=1,KSEA)
      WRITE (KOUT,42) (MON,FDRY(MON),MON=1,KSEA)
      READ (IN,70) (SSCON(I),I=1,NWS)
      WRITE (KOUT,41) (I,SSCON(I),I=1,NWS)
      CALL WNDSCE(WINDS)
 7600 CONTINUE
      READ (IN,61) ICHO
      IF (ICHO.EQ.2) GO TO 7800
 7700 CALL DCAL(PKAPPA, QKAPPA, WINDS, WINDSD, JSTAB, GRATE, GFRACT,
     *      IPTYPE, DF1, DF2)
      GO TO 7900
 7800 CALL MAXCON(PKAPPA, QKAPPA, WINDSD, JSTAB, GRATE, GFRACT,
     *      IPTYPE, DF1, DF2)
 7900 GO TO 2300
 8000 STOP
   99 FORMAT (10A8)
   98 FORMAT (1H1, 10X, 10A8)
   97 FORMAT (3I5, E10.0)
   96 FORMAT (27H0 PASQUILL STABILITIES USED/)
   95 FORMAT (46H0 PASQUILL STABILITIES NOT USED--STABILITIES F,
     *      8HOUND IN , 16HSUBROUTINE SIGMA/)
   94 FORMAT (46H0 FORMULATION BY HOSKER OF BRIGGS-SMITH DISPER,
     *      8HSION VAL, 3HUES/)
   93 FORMAT (26H0 BRIGGS DISPERSION VALUES/)
   92 FORMAT (45H0 DISPERSION COEFFICIENTS FOR STABILITY CLASS/1H0,
     *      14X, 4HX(M), 15X, 1HA, 14X, 1HB, 14X, 1HC, 14X, 1HD, 14X,
     *      1HE, 14X, 1HF/)
   91 FORMAT (10X, F9.1, 5X, 6E15.5)
   90 FORMAT (12H0 ROUGHNESS=, 2X, E10.3, 2X, 6HMETERS)
   89 FORMAT (1H0, 9X, 22HNUMBER OF WIND SPEEDS=, I5/10X, 8HNUMBER O,
     *      1HF, 17H WIND DIRECTIONS=, I5/10X, 7HNUMBER , 9HOF WIND S,
     *      11HTABILITIES=, I5/10X, 16HSTABILITIES USED, 3H---, 7I5)
   88 FORMAT (41H0 SIGMAX FOR EACH STABILITY IN THE TABLE=, 7F8.0)
   87 FORMAT (7(2X, A8))
   86 FORMAT (A4)
   85 FORMAT (6X, 8F7.4)
   84 FORMAT (37H0 STABILITY WIND ROSE DATA FOR PERIOD, I4, 2X, A8)
   83 FORMAT (50X, 15HSTABILITY CLASS, I5)
   82 FORMAT (1X, 9HDIRECTION, I3, 5X, 6F12.6)
   81 FORMAT (16I5)
   80 FORMAT (//10X, 10HNO SOURCES//)
   79 FORMAT (//10X, 9HNO GAUGES//)
   78 FORMAT (16L5)
   77 FORMAT (50H0 LATITUDE, LONGITUDE AND HEIGHT OF GAUGE SAMPLING,
     *      7H POINTS/1H0)
   76 FORMAT (10H ID NUMBER, 6X, 4HNAME, 5X, 8HLATITUDE, 22X,
     *      7HLONGITU, 2HDE/23X, 7HDEGREES, 3X, 7HMINUTES, 3X,
     *      7HSECONDS, 3X, 7HDEGREES, 3X, 7HMINUTES, 3X, 7HSECONDS)
   75 FORMAT (I10, 2X, A8, 6F10.2, F13.1)
   74 FORMAT (41H0 LATITUDE AND LONGITUDE OF POINT SOURCES/)
   73 FORMAT (47H0 LATITUDE, LONGITUDE AND HEIGHT OF AREA SOURCE,
     *      10H CENTROIDS/)
   72 FORMAT (47H0 LATITUDE, LONGITUDE AND HEIGHT OF LINE SOURCE.
     *      10H ENDPOINTS/)
   71 FORMAT (1H0)
   70 FORMAT (7E10.3)
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69 FORMAT (32H0 AREA SOURCE AREAS IN METERS**2)
68 FORMAT (13H  AREA SOURCE, I3, 2X, A8, 2X, 1PE10.3/)
67 FORMAT (1H0/1H0)
66 FORMAT (/36X, 16HSTACK CONDITIONS//8H  SOURCE, 5X, 4HNAME, 4X,
  *     9HHEIGHT(M), 12H AMB TEMP(K), 11H ST TEMP(K), 9H RADIUS(M,
  *     1H), 14H EXIT VEL(M/S))
65 FORMAT (6H POINT, I3, 2X, A8, F8.1, 1X, 2F11.1, F10.1, F12.2)
64 FORMAT (//33H  WIND SPEEDS (M/S) AT HEIGHT OF , F3.0, 2H M//9X,
  *     8F8.2//)
63 FORMAT (/2X, 27HWIND SPEEDS (M/S) AT POINT , I2, 11H  SOURCE HE,
  *     8HIGHT AS , 23HA FUNCTION OF STABILITY//)
62 FORMAT (7X, I2, 8F8.2)
61 FORMAT (I5, F5.0)
60 FORMAT (13H0 GRASS COVER, F5.1)
59 FORMAT (14H0 FOREST COVER, F5.1)
58 FORMAT (30H0 AFTERNOON MIXING HEIGHTS(M)=, 14F5.0)
57 FORMAT (30H0 NOCTURNAL MIXING HEIGHTS(M)=, 14F5.0)
56 FORMAT (//10X, 13HNO POLLUTANTS//)
55 FORMAT (I5, 3E10.0, I2, 2X, A8)
54 FORMAT (/10X, 18HDATA FOR POLLUTANT, I4, 2X, A8, 1X, 8H(A PARTI,
  *     1HC, 1HU, 5HLATE)/10X, 18HPARTICLE DIAMETER=, 1PE12.3, 2X,
  *     7HMICRONS/10X, 17HPARTICLE DENSITY=, 1PE12.3, 2X, 5HG/CM*,
  *     2H*3/10X, 10HHALF LIFE=, 1PE12.3, 2X, 7HSECONDS)
53 FORMAT (/10X, 18HDATA FOR POLLUTANT, I4, 2X, A8, 1X, 7H(A GAS)/
  *     10X, 25HBOUNDARY LAYER THICKNESS=, 1PE12.3, 2X, 6HMETERS/
  *     10X, 22HDIFFUSION CONSTANT FOR, 9H WASHOUT=, 1PE12.3, 2X,
  *     9HMETER**2/, 3HSEC, 10X, 10HHALF LIFE=, 1PE12.3, 2X,
  *     7HSECONDS)
52 FORMAT (36H1 POINT SOURCE EMISSIONS FOR PERIODS/8(I5, 2X, A8))
51 FORMAT (33H0 EMISSION RATE FROM POINT SOURCE, I4, 2X, 7HOF POLL,
  *     2HUT, 3HANT, I4, 2X, 12HIN GRAMS/SEC/8(1PE15.4))
50 FORMAT (35H0 AREA SOURCE EMISSIONS FOR PERIODS/8(I5, 2X, A8))
49 FORMAT (32H0 EMISSION RATE FROM AREA SOURCE, I4, 2X, 8HOF POLLU,
  *     1HT, 3HANT, I4, 2X, 17HIN GRAMS/M**2/SEC/8(1PE15.4))
48 FORMAT (35H0 LINE SOURCE EMISSIONS FOR PERIODS/8(I5, 2X, A8))
47 FORMAT (32H0 EMISSION RATE FROM LINE SOURCE, I4, 2X, 8HOF POLLU,
  *     1HT, 3HANT, I4, 2X, 14HIN GRAMS/M/SEC/8(1PE15.4))
46 FORMAT (13H0 AREA SOURCE, I4, 2X, 1H=, 2X, 11HWINDBLOWN S,
  *     5HOURCE, I4, 2X, A8)
45 FORMAT (I10, 3E10.0)
44 FORMAT (////33H0INFORMATION FOR WINDBLOWN SOURCE, I4//(10X,
  *     6HITYPE=, I4/10X, 8HDENSITY=, E12.4, 2X, 7HG/CM**3/10X,
  *     19HSALTATION DIAMETER=, E12.4, 2X, 6HMETERS/10X, 7HSUSPENS,
  *     2HIO, 11HN DIAMETER=, E12.4, 2X, 6HMETERS/))
43 FORMAT (10X, 41HCONCENTRATION FACTOR FOR WINDBLOWN SOURCE,
  *     I5//(10X, 9HPOLLUTANT, I5, 1PE15.4/))
42 FORMAT (10X, 42HFRACTION OF TIME SOURCE REMAINS DRY DURING/(10X,
  *     6HSEASON, I5, 2X, 1H=, F10.5))
41 FORMAT (///10X, 38HSUSPENSION TO SALTATION RATIOS FOR SOU,
  *     3HRCE, I4, 2X, 1H=, E12.4, 2X, 7H1/METER)
40 FORMAT (10X, 10HPOLLUTANT , I2, 28H IS THE DAUGHTER OF POLLUTAN,
  *     2HT , I2)
39 FORMAT (1H1, 42HGAGE BACKGROUND CONCENTRATIONS FOR PERIODS,
  *     /8(I5, 2X, A8))
38 FORMAT (1H , 25HBG CONCENTRATION FOR GAGE, I4, 2X, 9HOF POLLUT,
  *     2HAN, 1HT, I4, 2X, 13HIN GRAMS/M**3, /8(1PE15.4))
37 FORMAT (7F10.5, 2X, A8)
36 FORMAT (10H ID NUMBER, 6X, 4HNAME, 5X, 8HLATITUDE, 22X,
  *     7HLONGITU, 2HDE/23X, 7HDEGREES, 3X, 7HMINUTES, 3X,
  *     7HSECONDS, 3X, 7HDEGREES, 3X, 7HMINUTES, 3X, 7HSECONDS,
  *     5X, 9HHEIGHT(M))
   END
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      BLOCK DATA                                                        BLK
      COMMON /C1/ XM(50), SIGTAB(6,50), SIGMAX(6), V(20), DV(20),       BLK
     *     CLAMDA(20), DLAMDA(40,12,20), NDIST, NSTAB                   BLK
      DIMENSION SIGTA1(6,19), SIGTA2(6,19), SIGTA3(6,12)                BLK
      EQUIVALENCE (SIGTAB(1,1),SIGTA1(1,1)), (SIGTAB(1,20),SIGTA2(1,1)),BLK
     *     (SIGTAB(1,39),SIGTA3(1,1))                                   BLK
      DATA NDIST /50/, NSTAB /6/                                        BLK
      DATA SIGMAX /0.320E4,0.160E4,0.800E3,0.500E3,0.200E3,0.100E3/     BLK
      DATA XM /1.000E+00,2.000E+00,3.000E+00,4.000E+00,5.000E+00,       BLK
     *     1.000E+01,1.500E+01,2.000E+01,2.500E+01,3.000E+01,3.500E+01, BLK
     *     4.000E+01,4.500E+01,5.000E+01,1.000E+02,2.000E+02,3.000E+02, BLK
     *     4.000E+02,5.000E+02,6.000E+02,7.000E+02,8.000E+02,9.000E+02, BLK
     *     1.000E+03,1.100E+03,1.200E+03,1.300E+03,1.400E+03,1.600E+03, BLK
     *     1.800E+03,2.000E+03,2.500E+03,3.000E+03,3.500E+03,4.000E+03, BLK
     *     4.500E+03,5.000E+03,6.000E+03,7.000E+03,8.000E+03,1.000E+04, BLK
     *     1.500E+04,2.000E+04,3.000E+04,4.000E+04,5.000E+04,6.000E+04, BLK
     *     7.000E+04,8.000E+04,1.000E+05/                               BLK
      DATA SIGTA1 /7.963E-02,1.000E-01,1.070E-01,9.319E-02,4.744E-02,   BLK
     *     1.924E-02,1.752E-01,2.000E-01,2.025E-01,1.681E-01,8.856E-02, BLK
     *     3.743E-02,2.778E-01,3.000E-01,2.941E-01,2.374E-01,1.276E-01, BLK
     *     5.524E-02,3.854E-01,4.000E-01,3.832E-01,3.033E-01,1.653E-01, BLK
     *     7.282E-02,4.968E-01,5.000E-01,4.704E-01,3.668E-01,2.021E-01, BLK
     *     9.021E-02,1.093E+00,1.000E+00,8.900E-01,6.618E-01,3.773E-01, BLK
     *     1.755E-01,1.733E+00,1.500E+00,1.292E+00,9.346E-01,5.435E-01, BLK
     *     2.590E-01,2.404E+00,2.000E+00,1.684E+00,1.194E+00,7.042E-01, BLK
     *     3.413E-01,3.099E+00,2.500E+00,2.067E+00,1.444E+00,8.610E-01, BLK
     *     4.229E-01,3.813E+00,3.000E+00,2.445E+00,1.686E+00,1.015E+00, BLK
     *     5.037E-01,4.544E+00,3.500E+00,2.817E+00,1.923E+00,1.166E+00, BLK
     *     5.841E-01,5.290E+00,4.000E+00,3.186E+00,2.154E+00,1.313E+00, BLK
     *     6.639E-01,6.048E+00,4.500E+00,3.550E+00,2.382E+00,1.462E+00, BLK
     *     7.434E-01,6.818E+00,5.000E+00,3.912E+00,2.605E+00,1.607E+00, BLK
     *     8.225E-01,1.600E+01,1.090E+01,7.900E+00,4.950E+00,3.250E+00, BLK
     *     1.650E+00,3.300E+01,2.000E+01,1.400E+01,8.480E+00,5.600E+00, BLK
     *     3.112E+00,6.255E+01,3.129E+01,2.053E+01,1.198E+01,8.129E+00, BLK
     *     4.593E+00,9.847E+01,4.299E+01,2.694E+01,1.530E+01,1.059E+01, BLK
     *     6.054E+00,1.400E+02,5.500E+01,3.326E+01,1.850E+01,1.300E+01, BLK
     *     7.500E+00/                                                   BLK
      DATA SIGTA2 /2.113E+02,6.965E+01,3.951E+01,2.137E+01,1.493E+01,   BLK
     *     8.720E+00,2.994E+02,8.505E+01,4.570E+01,2.414E+01,1.678E+01, BLK
     *     9.904E+00,4.047E+02,1.011E+02,5.184E+01,2.682E+01,1.857E+01, BLK
     *     1.106E+01,5.281E+02,1.178E+02,5.794E+01,2.944E+01,2.031E+01, BLK
     *     1.219E+01,6.696E+02,1.350E+02,6.400E+01,3.200E+01,2.200E+01, BLK
     *     1.330E+01,9.152E+02,1.562E+02,6.962E+01,3.421E+01,2.345E+01, BLK
     *     1.430E+01,1.217E+03,1.785E+02,7.517E+01,3.636E+01,2.486E+01, BLK
     *     1.527E+01,1.583E+03,2.017E+02,8.068E+01,3.846E+01,2.623E+01, BLK
     *     1.623E+01,2.018E+03,2.259E+02,8.613E+01,4.050E+01,2.756E+01, BLK
     *     1.717E+01,3.126E+03,2.772E+02,9.690E+01,4.448E+01,3.014E+01, BLK
     *     1.900E+01,3.200E+03,3.319E+02,1.075E+02,4.830E+01,3.261E+01, BLK
     *     2.077E+01,3.200E+03,3.900E+02,1.180E+02,5.200E+01,3.500E+01, BLK
     *     2.250E+01,3.200E+03,6.131E+02,1.421E+02,6.022E+01,3.991E+01, BLK
     *     2.506E+01,3.200E+03,8.874E+02,1.653E+02,6.789E+01,4.443E+01, BLK
     *     2.736E+01,3.200E+03,1.213E+03,1.879E+02,7.514E+01,4.864E+01, BLK
     *     2.947E+01,3.200E+03,1.590E+03,2.100E+02,8.203E+01,5.262E+01, BLK
     *     3.143E+01,3.200E+03,1.600E+03,2.316E+02,8.864E+01,5.639E+01, BLK
     *     3.327E+01,3.200E+03,1.600E+03,2.528E+02,9.500E+01,6.000E+01, BLK
     *     3.500E+01,3.200E+03,1.600E+03,2.942E+02,1.052E+02,6.576E+01, BLK
     *     3.782E+01/                                                   BLK
      DATA SIGTA3 /3.200E+03,1.600E+03,3.345E+02,1.147E+02,7.105E+01,   BLK
     *     4.038E+01,3.200E+03,1.600E+03,3.738E+02,1.236E+02,7.598E+01, BLK
     *     4.274E+01,3.200E+03,1.600E+03,4.500E+02,1.400E+02,8.500E+01, BLK
     *     4.700E+01,3.200E+03,1.600E+03,6.161E+02,1.750E+02,9.884E+01, BLK
     *     5.422E+01,3.200E+03,1.600E+03,7.700E+02,2.050E+02,1.100E+02, BLK
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     *     6.000E+01,3.200E+03,1.600E+03,8.000E+02,2.479E+02,1.254E+02,  BLK   630
     *     6.645E+01,3.200E+03,1.600E+03,8.000E+02,2.837E+02,1.376E+02,  BLK   640
     *     7.145E+01,3.200E+03,1.600E+03,8.000E+02,3.150E+02,1.479E+02,  BLK   650
     *     7.558E+01,3.200E+03,1.600E+03,8.000E+02,3.480E+02,1.569E+02,  BLK   660
     *     7.913E+01,3.200E+03,1.600E+03,8.000E+02,3.786E+02,1.649E+02,  BLK   670
     *     8.227E+01,3.200E+03,1.600E+03,8.000E+02,4.072E+02,1.721E+02,  BLK   680
     *     8.508E+01,3.200E+03,1.600E+03,8.000E+02,4.600E+02,1.850E+02,  BLK   690
     *     9.000E+01/                                                    BLK   700
      END                                                                BLK   710
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      SUBROUTINE DCAL(PKAPPA, QKAPPA, WINDS, WINDSD, JSTAB, GRATE,
     *    GFRACT, IPTYPE, DF1, DF2)
      LOGICAL SKIPP, SKIPA, SKIPL, SKIPG, SKIPOL
      REAL LSTHA, LFTHA, LSPHI, LFPHI
      REAL LQIO, KCOVER
      DOUBLE PRECISION ATITLE, SEANAM, GNAME, PNAME, ANAME, LNAME,
     *    POLNAM
      COMMON /C1/ XM(50), SIGTAB(6,50), SIGMAX(6), V(20), DV(20),
     *    CLAMDA(20), DLAMDA(40,12,20), NDIST, NSTAB
      COMMON /C2/ H
      COMMON /C3/ PI, R, KOUT
      COMMON /C4/ DP(40,10), DA(40,10), DIRP(40,10), DIRA(40,10),
     *    AREA(10)
      COMMON /C5/ DTH(40,10), R1(40,10), R2(40,10), TH1(40,10),
     *    TH2(40,10)
      COMMON /C6/ FREQ(12,7,8,16), HGT(10), PQIO(10,20,12), IPAR(20),
     *    AQIO(10,20,12), LQIO(10,20,12), THALF(20), HMIX(8,12)
      COMMON /C8/ NG, NP, NA, NL, NWS, NPOL, NFSTAB, NWINDS, WW, WF,
     *    FDRY(12)
      COMMON /C9/ COPT(40,20,12), HTG(40)
      COMMON /C10/ LSTHA(10), LFTHA(10), LSPHI(10), LFPHI(10)
      COMMON /C11/ GTHA(40), GPHI(40), PTHA(10), PPHI(10), ATHA(10),
     *    APHI(10)
      COMMON /C12/ WQIO(3,5,8), VFALL(3)
      COMMON /C13/ HGA(10), HGL(10)
      COMMON /C14/ KDISP, KCOVER, ROUGH
      COMMON /C15/ SKIPP(10), SKIPA(10), SKIPL(10), SKIPG(40),
     *    SKIPOL(20)
      COMMON /C16/ KSEA
      COMMON /C18/ ATITLE(10), SEANAM(12), GNAME(40), PNAME(10),
     *    ANAME(10), LNAME(10), POLNAM(20), COMP(32), F(32,40,10)
      DIMENSION DEPP(40,20,12), DEPA(40,20,12), DEPL(40,20,12)
      DIMENSION DEPT(40,20,12), DRYDEP(40,20,12), WETDEP(40,20,12)
      DIMENSION PKAPPA(10), WINDSD(8,7,10), JSTAB(7), WINDS(8)
      DIMENSION GRATE(40,12), GFRACT(40,12), IPTYPE(20), DF1(20),
     *    DF2(20)
      DIMENSION FREQX(20), COPA(40,20,12), COPL(40,20,12),
     *    COPP(40,20,12), QKAPPA(10), SURF(40)
C ***  DEPP(I,M,MON)=DEPOSITION RATE IN GRAMS/METER**2/SEC FOR POLLUTANT
C ***  M,AT SAMPLING POINT I, DURING MONTH MON
C ***   IT1=1 FOR WETFALL CALL IN QQP, IT2=2 FOR DRYFALL CALL IN QQP
      IT1 = 1
      IT2 = 2
      CALL FALL(V, DV, IPTYPE, DF1, DF2)
      CALL WASH(IPTYPE, DF1, DF2, GRATE)
C ***SURF(N) SPECIFIES SURFACE CONDITIONS AT THE RECEPTOR
C ***UNLESS EXPLICITLY OVERRIDDEN VALUES DEFAULT TO KCOVER
      DO 10 I=1,NG
         SURF(I) = KCOVER
   10 CONTINUE
      IKPM = 1
      DO 40 I=1,NG
         DO 30 M=1,NPOL
            DO 20 MON=1,KSEA
               DEPP(I,M,MON) = 0.
               DEPA(I,M,MON) = 0.
               DEPL(I,M,MON) = 0.
               WETDEP(I,M,MON) = 0.
               DRYDEP(I,M,MON) = 0.
               COPP(I,M,MON) = 0.0
               COPA(I,M,MON) = 0.0
               COPL(I,M,MON) = 0.0
```

```
 20         CONTINUE
 30      CONTINUE
 40   CONTINUE
      IF (NP.EQ.0) GO TO 230
      DO 190 I=1,NG
         IF (SKIPG(I)) GO TO 190
         DO 180 MON=1,KSEA
            ISEA = MON
            DO 170 M=1,NPOL
               LL = IPAR(M)
               IF (SKIPOL(M)) GO TO 170
C ***  WW=WASHOUT WEIGHT,THE FRACTIONAL AMOUNT OF TIME DURING WHICH BOTH
C ***  WASHOUT AND FALLOUT OCCURS
C ***  WF=FALLOUT WEIGHT,FRACTIONAL AMOUNT OF TIME DURING WHICH ONLY
C ***  FALLOUT OCCURS
               WW = GFRACT(I,MON)
               WF = 1.0 - WW
               CLAMDA(M) = DLAMDA(I,MON,M)
               DO 160 J=1,NP
                  IF (SKIPP(J)) GO TO 160
                  FAC1 = PQIO(J,LL,MON)/DP(I,J)
                  FACWET = 2.543*CLAMDA(M)*WW*FAC1
                  IC = 0
                  DO 150 II=1,NFSTAB
                     FACTOR = 1.0
                     LN = 1
                     IF (II.NE.4) GO TO 50
                     IF (JSTAB(5).EQ.4) GO TO 50
                     FACTOR = 0.5
                     LN = 2
 50                  DO 140 L=1,LN
                        SMA = SIGMA(JSTAB(II),DP(I,J),IKPM,P)
                        FACDRY = 2.032*FAC1/SMA
                        FACEXP = -0.5/SMA**2
                        IC = IC + 1
                        DO 130 JJ=1,NWINDS
                           DTST = DIRP(I,J) + 11.25
                           IF (DTST.GT.360.) DTST = DTST - 360.
                           DTST = DTST/22.51
                           KK = DTST
                           KK = KK + 1
                           IF (FREQ(MON,II,JJ,KK).EQ.0.0) GO TO 130
                           IF (JSTAB(II).GT.4) GO TO 60
                           H = HGT(J) + PKAPPA(J)/WINDSD(JJ,II,J)
                           GO TO 70
 60                        H = HGT(J) + QKAPPA(J)/((WINDSD(JJ,II,J))**
     *                         .3333333)
 70                        CONTINUE
                           HOLD = H
                           H = HOLD - HTG(I)*0.5
                           IF (HTG(I).LT.0) H = HOLD - HTG(I)
                           IF (HTG(I).GE.HOLD) H = HOLD*0.5
                           IF (H.GT.1500.0) H = 1500.0
                           HH = H
                           IF (IPTYPE(M).EQ.2) GO TO 80
C THE PLUME WILL TILT FOR HEAVY PARTICLES
                           HH = H - V(M)*DP(I,J)/WINDSD(JJ,II,J)
                           IF (HH.LT.0.0) HH = 0.0
 80                        CONTINUE
                           CC = 0.0
                           TSMA = 2.0*SMA*SMA
```

```
                           DO 90 ITR=1,10
                              HIM = 2.0*FLOAT(ITR)*HMIX(IC,MON)
                              DMAX = HH + HIM
                              DMIN = HH - HIM
                              CP = DMAX*DMAX/TSMA
                              IF (CP.GT.50.0) CP = 50.0
                              CM = DMIN*DMIN/TSMA
                              IF (CM.GT.50.0) CM = 50.0
                              CN = EXP(-CP) + EXP(-CM)
                              CC = CC + CN
                              IF (ITR.EQ.1) GO TO 90
                              FRAC = CN/CC
                              IF (FRAC.LT.0.01) GO TO 100
   90                      CONTINUE
  100                      CONTINUE
                           QQP1 = QQP(JSTAB(II),M,DP(I,J),WINDSD(JJ,II,
     *                          J),IT1,IPTYPE(M),I,KCOVER)
                           QQP2 = QQP(JSTAB(II),M,DP(I,J),WINDSD(JJ,II,
     *                          J),IT2,IPTYPE(M),I,KCOVER)
                           XYZ = 0.693/THALF(LL)*DP(I,J)/WINDSD(JJ,II,J)
                           IF (XYZ.GT.50.0) XYZ = 50.0
                           FREQX(LL) = FACTOR*FREQ(MON,II,JJ,KK)/
     *                          WINDSD(JJ,II,J)
                           IF (LL.NE.M) GO TO 110
                           FREQW = FREQX(M)*EXP(-XYZ)
                           GO TO 120
  110                      FREQW = FREQX(LL)*(1.0-EXP(-XYZ))
  120                      XYZ = FACEXP*HH**2
                           IF (XYZ.LT.-50.0) XYZ = -50.0
                           DRY = FREQW*QQP2*FACDRY*(EXP(XYZ)+CC)
                           COPP(I,M,MON) = COPP(I,M,MON) + DRY
                           DRY = DRY*WF*SURF(I)*DV(M)
                           WET = FREQW*QQP1*FACWET
                           DEPP(I,M,MON) = DEPP(I,M,MON) + DRY + WET
                           DRYDEP(I,M,MON) = DRYDEP(I,M,MON) + DRY
                           WETDEP(I,M,MON) = WETDEP(I,M,MON) + WET
  130                   CONTINUE
  140                CONTINUE
  150             CONTINUE
  160          CONTINUE
  170       CONTINUE
  180    CONTINUE
  190 CONTINUE
      DO 220 M=1,NPOL
         IF (SKIPOL(M)) GO TO 220
         WRITE (KOUT,99999) M, POLNAM(M)
         WRITE (KOUT,99998) (SEANAM(MON),MON=1,KSEA)
         DO 200 I=1,NG
            IF (SKIPG(I)) GO TO 200
            WRITE (KOUT,99997) I, M, (DEPP(I,M,MON),MON=1,KSEA)
  200    CONTINUE
         WRITE (KOUT,99996)
         DO 210 I=1,NG
            IF (SKIPG(I)) GO TO 210
            WRITE (KOUT,99997) I, M, (COPP(I,M,MON),MON=1,KSEA)
  210    CONTINUE
  220 CONTINUE
C ***  DEPA(I,M,MON)=DEPOSITION RATE IN GRAMS/METER**2/SEC FOR POLLUTANT
C ***  M,AT SAMPLING POINT I,DURING MONTH MON,FOR ALL AREA SOURCES
  230 IF (NA.EQ.0) GO TO 390
      PI8 = PI/8.0
      NDIFF = NA - NWS
      DO 350 I=1,NG
```

```
      DO 340 MON=1,KSEA                                             DCA 1880
         ISEA = MON                                                 DCA 1890
         WW = GFRACT(I,MON)                                         DCA 1900
         WF = 1.0 - WW                                              DCA 1910
         DO 330 M=1,NPOL                                            DCA 1920
            IF (SKIPOL(M)) GO TO 330                                DCA 1930
            CLAMDA(M) = DLAMDA(I,MON,M)                             DCA 1940
            DO 320 K=1,NA                                           DCA 1950
               IF (SKIPA(K)) GO TO 320                              DCA 1960
               KW = K - NWS                                         DCA 1970
               H = HGA(K)                                           DCA 1980
               DELA = (R2(I,K)-R1(I,K))/3.                          DCA 1990
               DELAPA = DELA*PI8*AQIO(K,M,MON)                      DCA 2000
               FACWET = 2.543*DELAPA*WW*CLAMDA(M)                   DCA 2010
               DO 310 MM=1,3                                        DCA 2020
                  ADIS = R1(I,K) + FLOAT(MM)*DELA - DELA/2.         DCA 2030
                  DO 300 II=1,NFSTAB                                DCA 2040
                     SMA = SIGMA(JSTAB(II),ADIS,IKPM,P)             DCA 2050
                     DPAS = DELAPA/SMA                              DCA 2060
                     FACDRY = 2.032*DPAS                            DCA 2070
                     FACEXP = -0.5/SMA**2                           DCA 2080
                     P = P + 2.0                                    DCA 2090
                     DO 290 JJ=1,NWINDS                             DCA 2100
                        IF (K.GT.NDIFF) GO TO 270                   DCA 2110
                        QQA1 = QQP(JSTAB(II),M,ADIS,WINDS(JJ),IT1,  DCA 2120
     *                       IPTYPE(M),I,KCOVER)                    DCA 2130
                        QQA2 = QQP(JSTAB(II),M,ADIS,WINDS(JJ),IT2,  DCA 2140
     *                       IPTYPE(M),I,KCOVER)                    DCA 2150
                        HH = H                                      DCA 2170
                        IF (IPTYPE(M).EQ.2) GO TO 250               DCA 2180
                        HH = H - V(M)*ADIS/WINDS(JJ)                DCA 2190
                        IF (HH.LT.0.0) HH = 0.0                     DCA 2200
  250                   CONTINUE                                    DCA 2210
                        XYZ = FACEXP*HH**2                          DCA 2220
                        IF (XYZ.LT.-50.0) XYZ = -50.0               DCA 2230
                        QDRY = FACDRY*QQA2/WINDS(JJ)*EXP(XYZ)       DCA 2240
                        QWET = FACWET*QQA1/WINDS(JJ)                DCA 2250
                        XYZ = 0.693/THALF(M)*ADIS/WINDS(JJ)         DCA 2260
                        IF (XYZ.GT.50.0) XYZ = 50.0                 DCA 2270
                        DO 260 KK=1,16                              DCA 2280
                           IF (FREQ(MON,II,JJ,KK).EQ.0.0) GO TO 260 DCA 2290
                           FFREQ = F(KK,I,K)*FREQ(MON,II,JJ,KK)*    DCA 2300
     *                          EXP(-XYZ)                           DCA 2310
                           DRY = FFREQ*QDRY                         DCA 2320
                           COPA(I,M,MON) = COPA(I,M,MON) + DRY      DCA 2330
                           DRY = DRY*WF*SURF(I)*DV(M)               DCA 2340
                           WET = FFREQ*QWET                         DCA 2350
                           DEPA(I,M,MON) = DEPA(I,M,MON) + DRY + WET DCA 2360
                           DRYDEP(I,M,MON) = DRYDEP(I,M,MON) + DRY  DCA 2370
                           WETDEP(I,M,MON) = WETDEP(I,M,MON) + WET  DCA 2380
  260                   CONTINUE                                    DCA 2390
                        GO TO 290                                   DCA 2400
  270                   DO 280 KK=1,16                              DCA 2410
                           IF (FREQ(ISEA,II,JJ,KK).EQ.0.0) GO TO 280 DCA 2420
                           DRY = (1.016*WQIO(KW,M,JJ)*F(KK,I,K)*    DCA 2430
     *                          FREQ(ISEA,II,JJ,KK)*FDRY(ISEA)*DELA* DCA 2440
     *                          (PI/8.)*VFALL(KW)/(SMA*WINDS(JJ)))*  DCA 2450
     *                          EXP(-((VFALL(KW)/WINDS(JJ))*ADIS-HH)*DCA 2460
     *                          *2/(2.*SMA**2))*(2.-2./((1.-0.5*P)*  DCA 2470
     *                          (WINDS(JJ)*HH/(ADIS*VFALL(KW))-1.)   DCA 2480
     *                          +2.))                                DCA 2490
                           COPA(I,M,MON) = COPA(I,M,MON) +          DCA 2500
```

```
     *                                (DRY/VFALL(KW))
C WET=0.
                           DRYDEP(I,M,MON) = DRYDEP(I,M,MON) + DRY
                           DEPA(I,M,MON) = DEPA(I,M,MON) + DRY
  280                    CONTINUE
  290                 CONTINUE
  300              CONTINUE
  310           CONTINUE
  320        CONTINUE
  330     CONTINUE
  340  CONTINUE
  350 CONTINUE
      DO 380 M=1,NPOL
         IF (SKIPOL(M)) GO TO 380
         WRITE (KOUT,99995) M, POLNAM(M)
         DO 360 I=1,NG
            IF (SKIPG(I)) GO TO 360
            WRITE (KOUT,99997) I, M, (DEPA(I,M,MON),MON=1,KSEA)
  360    CONTINUE
         WRITE (KOUT,99994)
         DO 370 I=1,NG
            IF (SKIPG(I)) GO TO 370
            WRITE (KOUT,99997) I, M, (COPA(I,M,MON),MON=1,KSEA)
  370    CONTINUE
  380 CONTINUE
C ***  DEPL(I,M,MON)=DEPOSITION RATE IN GRAMS/METER**2/SEC FOR POLLUTANT
C ***  M,AT SAMPLING POINT I, DURING MONTH MON, FOR ALL LINE SOURCES
  390 IF (NL.EQ.0) GO TO 520
      DO 480 I=1,NG
         IF (SKIPG(I)) GO TO 480
         DO 470 MON=1,KSEA
            ISEA = MON
            WW = GFRACT(I,MON)
            WF = 1.0 - WW
            DO 460 M=1,NPOL
               IF (SKIPOL(M)) GO TO 460
               CLAMDA(M) = DLAMDA(I,MON,M)
               DO 450 L=1,NL
                  IF (SKIPL(L)) GO TO 450
                  H = HGL(L)
                  DD = R*SQRT((LSTHA(L)-LFTHA(L))**2+COS(LSTHA(L))*
     *                 COS(LFTHA(L))*(LFPHI(L)-LSPHI(L))**2)
                  DLEN = DD
                  DD = DD/9.
                  DTHL = (LFTHA(L)-LSTHA(L))/9.
                  DPHL = (LFPHI(L)-LSPHI(L))/9.
                  DO 440 NN=1,9
                     THAL = LSTHA(L) + FLOAT(NN-1)*DTHL + DTHL/2.
                     PHIL = LSPHI(L) + FLOAT(NN-1)*DPHL + DPHL/2.
                     DL = R*SQRT((GTHA(I)-THAL)**2+COS(GTHA(I))*
     *                    COS(THAL)*(GPHI(I)-PHIL)**2)
                     A = DD/DL
                     IF (A.GT.0.3927) A = 0.3927
C ***  0.3927=22.5*PI/180.
                     FAC1 = A*LQIO(L,M,MON)
                     FACWET = FAC1*2.543*CLAMDA(M)*WW
                     T1L = (GPHI(I)-PHIL)*COS(GTHA(I))
                     T2L = THAL - GTHA(I)
                     IF (T1L.NE.0.0) GO TO 400
                     IF (T2L.NE.0.0) GO TO 400
                     WRITE (KOUT,99993)
                     STOP
  400                CONTINUE
```

```
      IF (SKIPG(I)) GO TO 540
      WRITE (KOUT,99987)
      DO 530 MON=1,KSEA
        DEPT(I,M,MON) = DEPP(I,M,MON) + DEPA(I,M,MON) +
     *       DEPL(I,M,MON)
        COPT(I,M,MON) = COPT(I,M,MON) + COPP(I,M,MON) +
     *       COPA(I,M,MON) + COPL(I,M,MON)
        WRITE (KOUT,99986) I, M, MON, SEANAM(MON),
     *       DRYDEP(I,M,MON), WETDEP(I,M,MON), DEPT(I,M,MON),
     *       COPT(I,M,MON)
C ** THE FOLLOWING LINES PROVIDE FOR A PUNCH OUTPUT IF DESIRED.
C         WRITE(7,2186) I,M,MON,SEANAM(MON),COPT(I,M,MON)
C2186  FORMAT(3I5,2X,A8,1PE15.3)
C       WRITE(7,2187) GTHA(I),GPHI(I),I,MON,SEANAM(MON),COPT(I,M,MON)
C2187 FORMAT(2F8.6,2I2,2X,A8,1PE12.3)
  530       CONTINUE
  540    CONTINUE
  550 CONTINUE
      RETURN
99999 FORMAT (11H1 POLLUTANT, I3, 3H,  , A8, 5X, 17HPOINT SOURCE DEPO,
     *    2HSI, 23HTION RATE (GM/M**2/SEC))
99998 FORMAT (11H0 GAGE  POL, 12(2X, A8)/10X, 12(2X, A8))
99997 FORMAT (2I5, 12(1PE10.3)/10X, 12(1PE10.3))
99996 FORMAT (30X, 47HPOINT SOURCE INCREMENT TO CONCENTRATION (G/M**3,
     *    1H))
99995 FORMAT (11H0 POLLUTANT, I3, 3H,  , A8, 5X, 17HAREA SOURCE DEPOS,
     *    2HIT, 22HION RATE (GM/M**2/SEC))
99994 FORMAT (30X, 47HAREA SOURCE INCREMENT TO CONCENTRATION (G/M**3))
99993 FORMAT (////10X, 43H****SAMPLING POINT MAY NOT COINCIDE WITH LI,
     *    2HNE, 12H SOURCE****//)
99992 FORMAT (14H0 LINE LENGTH=, F10.1, 2H M)
99991 FORMAT (11H0 POLLUTANT, I3, 3H,  , A8, 5X, 17HLINE SOURCE DEPOS,
     *    2HIT, 22HION RATE (GM/M**2/SEC))
99990 FORMAT (30X, 47HLINE SOURCE INCREMENT TO CONCENTRATION (G/M**3))
99989 FORMAT (1H1, 10A8)
99988 FORMAT (11H0 POLLUTANT, I3, 3H,  , A8/20H0GAGE  POL    PERIOD,
     *    12X, 6HDRYDEP, 9X, 6HWETDEP, 8X, 9HTOTAL DEP, 11X, 4HCONC/
     *    30X, 10HG/M**2/SEC, 5X, 10HG/M**2/SEC, 5X, 10HG/M**2/SEC,
     *    9X, 6HG/M**3)
99987 FORMAT (1H0)
99986 FORMAT (3I5, 2X, A8, 4(1PE15.3))
      END
```

```
      SUBROUTINE FALL(V, DV, IPTYPE, DF1, DF2)
      REAL MU, G, KCOVER, KZ(7)
      DIMENSION V(20), DV(20), IPTYPE(20), DF1(20), DF2(20)
      COMMON /C8/ NG, NP, NA, NL, NWS, NPOL, NFSTAB, NWINDS, WW, WF,
     *     FDRY(12)
      COMMON /C14/ KDISP, KCOVER, ROUGH
      DATA MU /182.7E-6/,G /980.0/
C SUBROUTINE FALL CALCULATES THE TERMINAL VELOCITY OF PARTICLES
C AND THE DEPOSITION VELOCITY OF GASES.
C          VDEF IS THE DEFAULT DEPOSITION VELOCITY,NOT INCL. COVER
C          V(M) IS TERMINAL VELOCITY, DV(M) IS DEPOSITION VEL. INCL.
C          COVER, DVEFF=EFFECTIVE DEP.VEL. INCL.COVER
C MU=DYNAMIC VISCOSITY OF AIR(G/CM/SEC)=182.7E-6 AT 18C.
      GMU = G/(18.0*MU)
      VDEF = 0.01
      DVEFF = KCOVER*VDEF
      DO 20 M=1,NPOL
        IF (IPTYPE(M).EQ.2) GO TO 10
C CONVERT FROM MICRONS TO CM
        D = DF1(M)*1.0E-4
        V(M) = D**2*GMU*DF2(M)
C CONVERT FROM CM/SEC TO M/SEC
        V(M) = 0.01*V(M)
        DV(M) = V(M)
        IF (DVEFF.GE.V(M)) DV(M) = DVEFF
C V(M) IS A TERMINAL VELOCITY FOR PARTICLES AT THIS POINT.
        GO TO 20
   10   CONTINUE
        V(M) = 0.0
        DV(M) = VDEF
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FFAC(ROUGH, DIS, FF)
C** THIS PROGRAM IS DESIGNED TO USE A BICUBIC SPLINE (E02CBF) TO
C** INTERPOLATE ROUGHNESS LENGTH AND DISTANCE TO GET SMITH'S F-FACTOR.
      DIMENSION A(24), WORK(1000), XX(1), FF(1)
      DATA A /4.271283E+00,-1.6392801E-01,4.6154250E-03,
     *     -3.4015848E-03,3.3487470E-02,-1.5700273E-02,
     *     1.0613173E+00,-3.3861607E-01,2.2335016E-02,
     *     2.3207975E-02,2.9668740E-02,9.4169399E-04,
     *     1.6063944E-01,-8.0552405E-02,-2.9269821E-03,
     *     -4.8329144E-03,2.1975169E-02,-9.0408609E-03,
     *     -2.2467609E-02,2.8684347E-02,-2.1830132E-02,
     *     4.0820992E-03,1.5701951E-02,9.7306392E-04/
      DATA XMIN /-7.60090/, XMAX /2.70805/, YMIN /4.6/, YMAX
     *     /11.6/
      K = 3
      L = 5
      NA = (K+1)*(L+1)
      NWORK = 1000
      IFAIL = 1
      XX(1) = ALOG(ROUGH)
      YR = ALOG(DIS)
      IF (YR.LT.4.6) YR=4.6
      IF (YR.GT.11.6) YR=11.6
      CALL E02CBF(1, 1, K, L, XX, XMIN, XMAX, YR, YMIN, YMAX,
     *     FF, A, NA, WORK, NWORK, IFAIL)
      IF (IFAIL.NE.0) GO TO 10
      RETURN
   10 WRITE (6,99999) ROUGH, DIS, IFAIL
      STOP
99999 FORMAT (1X, 30HBICUBIC SPLINE FAILED, ROUGH= , F5.2,
     *     6H DIS= , F6.0, 17H METERS   IFAIL= , I2)
      END
```

```
      SUBROUTINE FRXTRN(FRACT, AVRATE, KSEA)
      DIMENSION FRACT(12), AVRATE(12)
C FRACT IS THE FRACTION OF THE MONTH PRECIP OCCURS
C AVRATE IS THE  AVERAGE RATE OF  PRECIP IN HUNDRETHS
C    OF AN INCH PER HOUR
      DO 10 MONT=1,KSEA
        FRACT(MONT) = 0.07
        AVRATE(MONT) = 08.5
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GEOMET(KTAG)
C PROGRAM CALCULATES GEOMETRIC VARIABLES FOR POINT AND AREA
      LOGICAL SKIPP, SKIPA, SKIPL, SKIPG, SKIPOL
      DOUBLE PRECISION ATITLE, SEANAM, GNAME, PNAME, ANAME, LNAME,
     *     POLNAM
      COMMON /C3/ PI, R, KOUT
      COMMON /C4/ DP(40,10), DA(40,10), DIRP(40,10), DIRA(40,10),
     *     AREA(10)
      COMMON /C5/ DTH(40,10), R1(40,10), R2(40,10), TH1(40,10),
     *     TH2(40,10)
      COMMON /C8/ NG, NP, NA, NL, NWS, NPOL, NFSTAB, NWINDS, WW, WF,
     *     FDRY(12)
      COMMON /C11/ GTHA(40), GPHI(40), PTHA(10), PPHI(10), ATHA(10),
     *     APHI(10)
      COMMON /C15/ SKIPP(10), SKIPA(10), SKIPL(10), SKIPG(40),
     *     SKIPOL(20)
      COMMON /C18/ ATITLE(10), SEANAM(12), GNAME(40), PNAME(10),
     *     ANAME(10), LNAME(10), POLNAM(20), COMP(32), F(32,40,10)
      IF (NP.EQ.0) GO TO 60
      DO 50 I=1,NG
         IF (SKIPG(I)) GO TO 50
         DO 40 J=1,NP
            IF (SKIPP(J)) GO TO 40
            IF (ABS(GTHA(I)-PTHA(J)).GT.0.0524) GO TO 10
            IF (ABS(GPHI(I)-PPHI(J)).GT.0.0524) GO TO 10
            DP(I,J) = R*SQRT((GTHA(I)-PTHA(J))**2+COS(GTHA(I))*
     *           COS(PTHA(J))*(GPHI(I)-PPHI(J))**2)
            GO TO 20
   10       DP(I,J) = R*ARCOS(COS(GTHA(I))*COS(PTHA(J))*COS(GPHI(I)
     *           -PPHI(J))+SIN(GTHA(I))*SIN(PTHA(J)))
   20       T1P = (GPHI(I)-PPHI(J))*COS(GTHA(I))
            T2P = PTHA(J) - GTHA(I)
            IF (T1P.NE.0.0 .OR. T2P.NE.0.0) GO TO 30
            WRITE (KOUT,99999)
            STOP
   30       DIRP(I,J) = 180.*(ATAN2(T1P,T2P))/PI
            IF (DIRP(I,J).LT.0.0) DIRP(I,J) = 360. + DIRP(I,J)
            IF (KTAG.EQ.2) GO TO 40
            WRITE (KOUT,99998) I, J, DP(I,J)
            WRITE (KOUT,99997) I, J, DIRP(I,J)
   40    CONTINUE
   50 CONTINUE
   60 CONTINUE
      IF (NA.EQ.0) GO TO 360
      DO 110 I=1,NG
         IF (SKIPG(I)) GO TO 110
         DO 100 K=1,NA
            IF (SKIPA(K)) GO TO 100
            IF (ABS(GTHA(I)-ATHA(K)).GT.0.0524) GO TO 70
            IF (ABS(GPHI(I)-APHI(K)).GT.0.0524) GO TO 70
            DA(I,K) = R*SQRT((GTHA(I)-ATHA(K))**2+COS(GTHA(I))*
     *           COS(ATHA(K))*(GPHI(I)-APHI(K))**2)
            GO TO 80
   70       DA(I,K) = R*ARCOS(COS(GTHA(I))*COS(ATHA(K))*COS(GPHI(I)
     *           -APHI(K))+SIN(GTHA(I))*SIN(ATHA(K)))
   80       T1A = (GPHI(I)-APHI(K))*COS(GTHA(I))
            T2A = ATHA(K) - GTHA(I)
            IF (T1A.NE.0.0 .OR. T2A.NE.0.0) GO TO 90
            WRITE (KOUT,99996)
            DA(I,K) = 1.0E-5
            GO TO 100
```

```
 180          CONTINUE
 190       CONTINUE
 200    CONTINUE
        DO 290 I=1,NG
           IF (SKIPG(I)) GO TO 290
           DO 280 K=1,NA
              IF (SKIPA(K)) GO TO 280
              DO 270 ID=1,32
                 IF (DTH(I,K).GE.360.) GO TO 260
                 IF (COMP(ID).GT.TH1(I,K)) GO TO 210
                 GO TO 270
 210             IF (COMP(ID).GT.TH2(I,K)) GO TO 220
                 GO TO 230
 220             F(ID,I,K) = 1.0
                 GO TO 280
 230             F(ID,I,K) = (COMP(ID)-TH1(I,K))/22.5
                 ID1 = ID + 1
                 IF (ID1.GT.31) GO TO 280
                 DO 250 IDP=ID1,32
                    IDS = IDP - 1
                    IF (COMP(IDP).GT.TH2(I,K)) GO TO 240
                    F(IDP,I,K) = 1.0
                    GO TO 250
 240                F(IDP,I,K) = (TH2(I,K)-COMP(IDS))/22.5
                    GO TO 280
 250             CONTINUE
 260             F(ID,I,K) = 1.0
 270          CONTINUE
 280       CONTINUE
 290    CONTINUE
        DO 320 I=1,NG
           IF (SKIPG(I)) GO TO 320
           DO 310 K=1,NA
              IF (SKIPA(K)) GO TO 310
              DO 300 ID=17,32
                 IDT = ID - 16
                 FTEST = F(IDT,I,K)**2
                 IF (FTEST.LT.1.0E-10) F(IDT,I,K) = F(ID,I,K)
 300          CONTINUE
 310       CONTINUE
 320    CONTINUE
        IF (KTAG.EQ.2) GO TO 360
        WRITE (KOUT,99990)
        DO 350 I=1,NG
           IF (SKIPG(I)) GO TO 350
           DO 340 K=1,NA
              IF (SKIPA(K)) GO TO 340
              WRITE (KOUT,99989) I, K
              DO 330 ID=1,16
                 FTEST2 = DTH(I,K)/22.5
                 TEST3 = F(ID,I,K)
                 IF (FTEST2.GE.1.0) FTEST2 = 1.0
                 IF (TEST3.GE.1.0) F(ID,I,K) = FTEST2
                 WRITE (KOUT,99988) ID, F(ID,I,K)
 330          CONTINUE
 340       CONTINUE
 350    CONTINUE
 360    RETURN
99999   FORMAT (1X, 48H*****SAMPLING POINT MAY NOT COINCIDE WITH POINT ,
     *       2HSO, 9HURCE*****)
99998   FORMAT (10X, 29HDISTANCE IN METERS FROM GAUGE, I3, 1X, 6HTO POI,
```

```
     *     2HNT, 7H SOURCE, I3, 1X, 1H=, E10.3 )                           GEO 1790
99997 FORMAT (10X, 42HDIRECTION IN DEG. CW FROM NORTH FROM GAUGE, I3,      GEO 1800
     *     1X, 15HTO POINT SOURCE, I3, 1X, 1H=, E10.3/)                    GEO 1810
99996 FORMAT (10X, 47HSAMPLING POINT COINCIDES WITH AREA SOURCE CENTR,     GEO 1820
     *     2HOI, 1HD)                                                      GEO 1830
99995 FORMAT (10X, 29HDISTANCE IN METERS FROM GAUGE, I3, 9H TO AREA ,      GEO 1840
     *     2HSO, 4HURCE, I3, 1X, 1H=, E10.3)                               GEO 1850
99994 FORMAT (10X, 42HDIRECTION IN DEG. CW FROM NORTH FROM GAUGE, I3,      GEO 1860
     *     1X, 14HTO AREA SOURCE, I3, 1X, 1H=, E10.3)                      GEO 1870
99993 FORMAT ( 10X, 46HANGULAR SPREAD(GREATER THAN 2 RADIANS) FROM GA,     GEO 1880
     *     1HU, 2HGE, I3, 1X, 7HTO AREA, I3, 1X, 1H=, E10.3/10X,           GEO 1890
     *     9HR1=0.0  R, 2H2=, 1X, E10.3)                                   GEO 1900
99992 FORMAT (10X, 31HANGULAR SPREAD =2*PI FROM GAUGE, I3, 1X,             GEO 1910
     *     6HTO ARE, 1HA, I3/10X, 11HR1=0.0  R2=, 1X, E10.3)               GEO 1920
99991 FORMAT ( 10X, 46HANGULAR SPREAD(LESS THAN 2 RADIANS) FROM GAUGE,     GEO 1930
     *     I3, 1X, 7HTO AREA, I3, 1X, 1H=, E10.3/10X, 3HR1=, 1X,           GEO 1940
     *     E10.3, 2X, 3HR2=, 1X, E10.3)                                    GEO 1950
99990 FORMAT (1HO, 10X, 33HSECTOR FRACTIONS FOR AREA SOURCES/1HO)          GEO 1960
99989 FORMAT (1HO, 10X, 26HSECTOR FRACTIONS FOR GAUGE, I3, 1X,             GEO 1970
     *     6HAND AR, 9HEA SOURCE, I3/)                                     GEO 1980
99988 FORMAT (10X, 19HFRACTION FOR SECTOR, I3, 1X, 1H=, F10.5)             GEO 1990
      END                                                                  GEO 2000
```

```
      SUBROUTINE MAXCON(PKAPPA, QKAPPA, WINDSD, JSTAB, GRATE, GFRACT,
     *     IPTYPE, DF1, DF2)
      LOGICAL SKIPP, SKIPA, SKIPL, SKIPG, SKIPOL
      REAL LQIO
      DIMENSION PKAPPA(10), WINDSD(8,7,10), JSTAB(7), CP1(40,10)
      DIMENSION GRATE(40,12), GFRACT(40,12),IPTYPE(20),DF1(20),DF2(20)
      DIMENSION QKAPPA(10)
      COMMON /C1/ XM(50), SIGTAB(6,50), SIGMAX(6), V(20), DV(20),
     *     CLAMDA(20), DLAMDA(40,12,20), NDIST, NSTAB
      COMMON /C2/ H
      COMMON /C3/ PI, R, KOUT
      COMMON /C4/ DP(40,10), DA(40,10), DIRP(40,10), DIRA(40,10),
     *     AREA(10)
      COMMON /C6/ FREQ(12,7,8,16), HGT(10), PQIO(10,20,12),
     *     AQIO(10,20,12), LQIO(10,20,12), THALF(20), HMIX(8,12)
      COMMON /C8/ NG, NP, NA, NL, NWS, NPOL, NFSTAB, NWINDS, WW, WF,
     *     FDRY(12)
      COMMON /C15/ SKIPP(10), SKIPA(10), SKIPL(10), SKIPG(40),
     *     SKIPOL(20)
      COMMON /C16/ KSEA
      CALL FALL(V, DV, IPTYPE, DF1, DF2)
      IF (NP.EQ.0) GO TO 130
      IKPM = 1
      DO 20 I=1,40
         DO 10 J=1,10
            CP1(I,J) = 0.0
   10    CONTINUE
   20 CONTINUE
      DO 120 I=1,NG
         IF (SKIPG(I)) GO TO 120
         DO 110 M=1,NPOL
            IF (SKIPOL(M)) GO TO 110
            DO 100 MON=1,KSEA
               DO 90 JWD=1,360,5
                  DO 80 JJ=1,NWINDS
                     DO 70 II=1,NFSTAB
                        SUM = 0.0
                        IQZ = JSTAB(II)
                        DO 60 J=1,NP
                           IF (SKIPP(J)) GO TO 60
                           IF (JSTAB(II).GT.4) GO TO 30
                           H = HGT(J) + PKAPPA(J)/WINDSD(JJ,II,J)
                           GO TO 40
   30                      H = HGT(J) + QKAPPA(J)/((WINDSD(JJ,II,J))**
     *                         .3333333)
   40                      CONTINUE
                           IF (H.GT.1500.0) H = 1500.0
                           HH = H
                           DIS = DP(I,J)
                           DIR = DIRP(I,J)
                           CALL SIGA(DIR, DIS, IQZ, SIGY, JWD, DIS2)
                           IF (IPTYPE(M).EQ.2) GO TO 50
C THE PLUME WILL NOW TILT FOR HEAVY PARTICLES
                           HH = H - V(M)*DIS2/WINDSD(JJ,II,J)
                           IF (HH.LT.0.0) HH = 0.0
   50                      CONTINUE
                           SMA = SIGMA(JSTAB(II),DIS2,IKPM,P)
                           DRY1 = 0.5*(HH/SMA)**2
                           IF (DRY1.GT.50.0) DRY1 = 50.0
                           DRY1 = PQIO(J,M,MON)*SIGY*EXP(-DRY1)
                           DRY2 = 3.14*SMA*WINDSD(JJ,II,J)
```

```
                    TAX = DRY1/DRY2*EXP(-0.693/THALF(M)*DIS/
     *                   WINDSD(JJ,II,J))
                    SUM = SUM + TAX
                    IF (SUM.LE.CP1(I,M)) GO TO 60
                    CP1(I,M) = SUM
                    LMON = MON
                    LJWD = JWD
                    LJJ = JJ
                    LII = II
                    LKK = J
   60             CONTINUE
   70          CONTINUE
   80       CONTINUE
   90    CONTINUE
  100    CONTINUE
         WRITE (KOUT,99999) I, M
         WRITE (KOUT,99998) LMON
         WRITE (KOUT,99997) LJWD
         WRITE (KOUT,99996) WINDSD(LJJ,LII,LKK)
         WRITE (KOUT,99995) LII
         WRITE (KOUT,99994) CP1(I,M)
  110   CONTINUE
  120 CONTINUE
  130 RETURN
99999 FORMAT (10X, 38HMAXIMUM HOURLY CONCENTRATION FOR GAUGE, I4, 1X,
     *     13HAND POLLUTANT, I4, 1X, 16HOCCURS DURING---)
99998 FORMAT (10X, 5HMONTH, I5)
99997 FORMAT (10X, 14HWIND DIRECTION, I5)
99996 FORMAT (10X, 10HWIND SPEED, F10.3)
99995 FORMAT (10X, 9HSTABILITY, I5)
99994 FORMAT (10X, 14HCONCENTRATION=, E10.3, 8HGMS/M**3)
      END
```

```
C***   NAG LIBRARY ROUTINES
      SUBROUTINE E02CBF(MFIRST, MLAST, K, L, X, XMIN, XMAX, Y,
     * YMIN, YMAX, FF, A, NA, WORK, NWORK, IFAIL)
C     MARK 7 RELEASE. NAG COPYRIGHT 1978.
C     EDITED BY JOYCE CLARKE OXFORD OEG NUCLEAR PHYSICS 05TH NOV 1976
C                 FORTRAN MACRO VERSION FDIA26.TEC
C
C     THIS SUBROUTINE EVALUATES A POLYNOMIAL OF DEGREE K AND L
C     RESPECTIVELY IN THE INDEPENDENT VARIABLES X AND Y.  THE
C     POLYNOMIAL IS GIVEN IN DOUBLE CHEBYSHEV SERIES FORM
C     A(I,J) * TI(XCAP) * TJ(YCAP),
C     SUMMED OVER I = 0,1,...K AND J = 0,1,...L WITH THE CONVENTION
C     THAT TERMS WITH EITHER I OR J ZERO ARE HALVED AND THE TERM
C     WITH BOTH I AND J ZERO IS MULTIPLIED BY 0.25. HERE TI(XCAP)
C     IS THE CHEBYSHEV POLYNOMIAL OF THE FIRST KIND OF DEGREE I
C     WITH ARGUMENT XCAP=((X - XMIN) - (XMAX - X))/(XMAX - XMIN).
C     TJ(YCAP) IS DEFINED SIMILARLY. THE COEFFICIENT A(I,J)
C     SHOULD BE STORED IN ELEMENT (L + 1)*I + J + 1 OF THE SINGLE
C     DIMENSION ARRAY A. THE EVALUATION IS PERFORMED FOR A SINGLE
C     GIVEN VALUE OF Y WITH EACH X VALUE GIVEN IN X(R), FOR R =
C     MFIRST, MFIRST+1,....,MLAST.
C
C     STARTED - 1978.
C     COMPLETED - 1978.
C     AUTHOR - GTA.
C
C     .. SCALAR ARGUMENTS ..
      REAL XMAX, XMIN, Y, YMAX, YMIN
      INTEGER IFAIL, K, L, MFIRST, MLAST, NA, NWORK
C     .. ARRAY ARGUMENTS ..
      REAL A(NA), FF(MLAST), WORK(NWORK), X(MLAST)
C     ..
C     .. LOCAL SCALARS ..
      DOUBLE PRECISION SRNAME
      REAL D, XCAP, YCAP
      INTEGER I, IERROR, KP1, LP1, M, R
C     .. FUNCTION REFERENCES ..
      INTEGER P01AAF
C     .. SUBROUTINE REFERENCES ..
C     E02AEF
C     ..
      DATA SRNAME /8H E02CBF /
      KP1 = K + 1
      LP1 = L + 1
      M = MLAST - MFIRST + 1
C
C     CHECK THAT THE INTEGER INPUT PARAMETERS HAVE REASONABLE
C     VALUES
C
      IERROR = 1
      IF (M.LE.0 .OR. K.LT.0 .OR. L.LT.0 .OR. NA.LT.KP1*LP1 .OR.
     * NWORK.LT.KP1) GO TO 80
C
C     CHECK THAT THE Y RANGE IS REASONABLE AND THAT THE GIVEN
C     VALUE OF Y IS NOT OUTSIDE IT
C
      IERROR = 2
      IF (YMIN.GE.YMAX .OR. Y.LT.YMIN .OR. Y.GT.YMAX) GO TO 80
      D = XMAX - XMIN
C
C     CHECK THAT THE X RANGE IS REASONABLE AND THAT NONE OF
C     THE GIVEN VALUES OF X IS OUTSIDE IT
```

```
C
      IERROR = 3
      IF (D.LE.0.0E+0) GO TO 80
      DO 20 R=MFIRST,MLAST
         IF (X(R).LT.XMIN .OR. X(R).GT.XMAX) GO TO 80
   20 CONTINUE
C
C     CALCULATE YCAP, THE NORMALIZED VALUE OF Y
C
      YCAP = ((Y-YMIN)-(YMAX-Y))/(YMAX-YMIN)
      IERROR = 1
      R = -L
C
C     EVALUATE THE COEFFICIENTS OF THE POLYNOMIAL FOR THE GIVEN Y
C
      DO 40 I=1,KP1
         R = R + LP1
         CALL E02AEF(LP1, A(R), YCAP, WORK(I), IERROR)
         IERROR = IERROR + 1
         IF (IERROR.NE.1) GO TO 80
   40 CONTINUE
C
C     EVALUATE THE POLYNOMAL AT THE GIVEN X VALUES
C
      DO 60 R=MFIRST,MLAST
         XCAP = ((X(R)-XMIN)-(XMAX-X(R)))/D
         IERROR = 1
         CALL E02AEF(KP1, WORK, XCAP, FF(R), IERROR)
         IF (IERROR.EQ.0) GO TO 60
         IERROR = 3
         GO TO 80
   60 CONTINUE
   80 IFAIL = P01AAF(IFAIL,IERROR,SRNAME)
      RETURN
      END
      SUBROUTINE E02AEF(NPLUS1, A, XCAP, P, IFAIL)
C     NAG LIBRARY SUBROUTINE  E02AEF
C
C     E02AEF  EVALUATES A POLYNOMIAL FROM ITS CHEBYSHEV-
C     SERIES REPRESENTATION.
C
C     CLENSHAW METHOD WITH MODIFICATIONS DUE TO REINSCH
C     AND GENTLEMAN.
C
C     USES NAG LIBRARY ROUTINES  P01AAF  AND  X02AAF.
C     USES INTRINSIC FUNCTION  ABS.
C
C     STARTED - 1973.
C     COMPLETED - 1976.
C     AUTHOR - MGC AND JGH.
C
C     NAG COPYRIGHT 1975
C     EDITED BY JOYCE CLARKE OXFORD OEG NUCLEAR PHYSICS 05TH NOV 1976
C                   FORTRAN MACRO VERSION FDIA26.TEC
C     MARK 5 RELEASE
C     MARK 7 REVISED IER-140 (DEC 1978)
      INTEGER NPLUS1, IFAIL, P01AAF, IERROR, K, KREV, N, NPLUS2
      DOUBLE PRECISION SRNAME
      REAL A(NPLUS1), XCAP, P, X02AAF, ABS, BK, BKP1, BKP2, DK,
     * ETA, FACTOR
      DATA SRNAME /8H E02AEF /
C
```

```
      IERROR = 0
      ETA = X02AAF(ETA)
C     INSERT CALL TO X02AAF
C
C     ETA  IS THE SMALLEST POSITIVE NUMBER SUCH THAT
C     THE COMPUTED VALUE OF  1.0 + ETA  EXCEEDS UNITY.
C
      IF (NPLUS1.GE.1) GO TO 10
      IERROR = 2
      GO TO 160
   10 IF (ABS(XCAP).LE.1.0+4.0*ETA) GO TO 20
      IERROR = 1
      P = 0.0
      GO TO 160
   20 IF (NPLUS1.GT.1) GO TO 40
      P = 0.5*A(1)
      GO TO 160
   40 N = NPLUS1 - 1
      NPLUS2 = N + 2
      K = NPLUS2
      IF (XCAP.GT.0.5) GO TO 120
      IF (XCAP.GE.-0.5) GO TO 80
C
C     GENTLEMAN*S MODIFIED RECURRENCE.
C
      FACTOR = 2.0*(1.0+XCAP)
      DK = 0.0
      BK = 0.0
      DO 60 KREV=1,N
         K = K - 1
         DK = A(K) - DK + FACTOR*BK
         BK = DK - BK
   60 CONTINUE
      P = 0.5*A(1) - DK + 0.5*FACTOR*BK
      GO TO 160
C
C     CLENSHAW*S ORIGINAL RECURRENCE.
C
   80 FACTOR = 2.0*XCAP
      BKP1 = 0.0
      BK = 0.0
      DO 100 KREV=1,N
         K = K - 1
         BKP2 = BKP1
         BKP1 = BK
         BK = A(K) - BKP2 + FACTOR*BKP1
  100 CONTINUE
      P = 0.5*A(1) - BKP1 + 0.5*FACTOR*BK
      GO TO 160
C
C     REINSCH*S MODIFIED RECURRENCE.
C
  120 FACTOR = 2.0*(1.0-XCAP)
      DK = 0.0
      BK = 0.0
      DO 140 KREV=1,N
         K = K - 1
         DK = A(K) + DK - FACTOR*BK
         BK = BK + DK
  140 CONTINUE
      P = 0.5*A(1) + DK - 0.5*FACTOR*BK
  160 IF (IERROR) 180, 200, 180
  180 IFAIL = P01AAF(IFAIL,IERROR,SRNAME)
```

```
      RETURN
  200 IFAIL = 0
      RETURN
      END
C     AUTO EDIT 20 SEP 76
      REAL FUNCTION X02AAF(X)
C     NAG COPYRIGHT 1975
C     EDITED BY JOYCE CLARKE OXFORD OEG NUCLEAR PHYSICS 03RD OCT 1976
C                    FORTRAN MACRO VERSION FDIA26.TEC
C     MARK 4.5 RELEASE

C     * EPS *
C     RETURNS THE VALUE EPS WHERE EPS IS THE SMALLEST
C     POSITIVE
C     NUMBER SUCH THAT 1.0 + EPS > 1.0
C     THE X PARAMETER IS NOT USED
C     FOR ICL 1900
C     X02AAF = 2.0**(-37.0)
      REAL X
      X02AAF = 2.0**(-20.0)
C     X02AAF = "146400000000
      RETURN
      END
      SUBROUTINE X04AAF(I,NERR)
C     MARK 7 RELEASE. NAG COPYRIGHT 1978
C     EDITED BY JOYCE CLARKE OXFORD OEG NUCLEAR PHYSICS 05TH NOV 1976
C                    FORTRAN MACRO VERSION FDIA26.TEC
C     IF I = 0, SETS NERR TO CURRENT ERROR MESSAGE UNIT NUMBER
C     (STORED IN NERR1).
C     IF I = 1, CHANGES CURRENT ERROR MESSAGE UNIT NUMBER TO
C     VALUE SPECIFIED BY NERR.
C
C     *** NOTE ***
C     THIS ROUTINE ASSUMES THAT THE VALUE OF NERR1 IS SAVED
C     BETWEEN CALLS.  IN SOME IMPLEMENTATIONS IT MAY BE
C     NECESSARY TO STORE NERR1 IN A LABELLED COMMON
C     BLOCK /AX02AA/ TO ACHIEVE THIS.
C
C     .. SCALAR ARGUMENTS ..
      INTEGER I, NERR
C     ..
C     .. LOCAL SCALARS ..
      INTEGER NERR1
C     ..
      DATA NERR1 /-1/
      IF (I.EQ.0) NERR = NERR1
      IF (I.EQ.1) NERR1 = NERR
      RETURN
      END
      INTEGER FUNCTION P01AAF(IFAIL, ERROR, SRNAME)
C     MARK 1 RELEASE.  NAG COPYRIGHT 1971
C     MARK 3 REVISED
C     MARK 4A REVISED, IER-45
C     MARK 4.5 REVISED
C     MARK 7 REVISED (DEC 1978) .... (APR 1979)
C     RETURNS THE VALUE OF ERROR OR TERMINATES THE PROGRAM.
C     IF A HARD FAILURE OCCURS, THIS ROUTINE CALLS A FORTRAN AUXILIARY
C     ROUTINE P01AAZ WHICH GIVES A TRACE, A FAILURE MESSAGE AND HALTS
C     THE PROGRAM
      INTEGER ERROR, IFAIL, NOUT
      DOUBLE PRECISION SRNAME
C     TEST IF NO ERROR DETECTED
      IF (ERROR.EQ.0) GO TO 20
C     DETERMINE OUTPUT UNIT FOR MESSAGE
```

```
      CALL X04AAF (0,NOUT)                                              39140000
C     TEST FOR SOFT FAILURE                                             39425000
      IF (MOD(IFAIL,10).EQ.1) GO TO 10                                  39710000
C     HARD FAILURE                                                      56000000
      WRITE (NOUT,99999) SRNAME, ERROR                                  60000000
C     STOPPING MECHANISM MAY ALSO DIFFER                                64000000
C     CALL P01AAZ (X)                                                   --------
      STOP                                                              66666000
C     SOFT FAIL                                                         76000000
C     TEST IF ERROR MESSAGES SUPPRESSED                                 77000000
   10 IF (MOD(IFAIL/10,10).EQ.0) GO TO 20                               78000000
      WRITE (NOUT,99999) SRNAME, ERROR                                  79000000
   20 P01AAF = ERROR                                                    80000000
      RETURN                                                            84000000
99999 FORMAT (1H0, 38HERROR DETECTED BY NAG LIBRARY ROUTINE , A8,       88000000
     * 11H - IFAIL = , I5//)                                            92000000
      END                                                               96000000
```

```
      SUBROUTINE PLUME(NP)
C ***  ST= STACK GAS TEMP (K), AT= AIR TEMP (K)
C ***  RAD= RADIUS OF STACK (M), VEL= STACK GAS EJECTION VEL. (M/SEC)
      COMMON /C20/ ST(10), AT(10), RAD(10), VEL(10), PKAPPA(10),
     *     QKAPPA(10)
      G = 9.8
      PTG = 0.01
      DO 30 I=1,NP
        S = PTG*G/AT(I)
        FB = G*VEL(I)*RAD(I)*RAD(I)*(ST(I)-AT(I))/AT(I)
        IF (FB.GT.55.) GO TO 10
        X = 14.*FB**0.625
        GO TO 20
   10   X = 34.*FB**0.4
   20   PKAPPA(I) = 1.6*FB**0.333333*(3.5*X)**0.666667
        QKAPPA(I) = 2.9*(FB/S)**0.333333
   30 CONTINUE
      RETURN
      END
```

```
      FUNCTION QQP(JSTAB, M, DIS, WIND, ISIG, IPTYPE, IGN, KCOVER)
      REAL KCOVER
      DIMENSION XX(50), FX(50), AX(50)
      COMMON /C1/ XM(50), SIGTAB(6,50), SIGMAX(6), V(20), DV(20),
     *      CLAMDA(20), DLAMDA(40,12,20), NDIST, NSTAB
      COMMON /C2/ H
      COMMON /C3/ PI, R, KOUT
      NS = JSTAB
      IF (NS.GT.6) NS = 6
      IKPM = 1
      SMA = SIGMA(NS,DIS,IKPM,P)
      SQRTPI = SQRT(2.0/PI)*KCOVER
      IKP = IKPM + 1
      DO 10 I=1,IKPM
        XX(I) = XM(I)
        HH = H - V(M)*XM(I)/WIND
        IF (HH.LT.0.0) HH = 0.0
        YY = 0.5*(HH/SIGTAB(NS,I))**2
        IF (YY.GT.40.0) YY = 40.0
        FX(I) = SQRTPI*EXP(-YY)/SIGTAB(NS,I)
   10 CONTINUE
      XX(IKP) = DIS
      ZZ = 0.5*(HH/SMA)**2
      IF (ZZ.GT.40.0) ZZ = 40.0
      FX(IKP) = SQRTPI*EXP(-ZZ)/SMA
      L = 1
      CALL SIMPUN(XX, FX, IKP, L, AX)
      IF (ISIG.EQ.1) GO TO 20
      QQP = EXP(-(DV(M)*AX(IKP)/DIS)*(DIS/WIND))
      GO TO 30
   20 QQP = EXP(-(CLAMDA(M)+DV(M)*AX(IKP)/DIS)*(DIS/WIND))
   30 RETURN
      END
```

```
      SUBROUTINE SIGA(DIR, DIS, NTYPE, SIGY, JWD, DIS2)
      REAL C3(7)
      DATA C3 /0.22,0.16,0.11,0.08,0.06,0.04,0.04/
      DIS2 = 1.0E-10
      WD = JWD
      A = DIR - WD
      A = ABS(A)
      ACID = 360.0 - A
      IF (A.GE.270.0) A = ACID
      IF (A.GE.90.0) GO TO 10
      A = A*0.01745
      Y = DIS*SIN(A)
      DIS2 = DIS*COS(A)
      IF (DIS2.LT.1.0) GO TO 10
      SIGY = DIS2*C3(NTYPE)/SQRT(1.0+0.0001*DIS2)
      B = Y/SIGY
      IF (B.GT.25.0) GO TO 10
      B = B*B/2.0
      IF (B.GT.50.0) GO TO 10
      B = EXP(-B)
      SIGY = B/SIGY
      GO TO 20
   10 SIGY = 0.0
   20 CONTINUE
      RETURN
      END
```

```
      FUNCTION SIGMA(JSTAB, DIS, IKPM, P)
      REAL KCOVER
      COMMON /C1/ XM(50), SIGTAB(6,50), SIGMAX(6), V(20), DV(20),
     *     CLAMDA(20), DLAMDA(40,12,20), NDIST, NSTAB
      COMMON /C14/ KDISP, KCOVER, ROUGH
      DIMENSION AONE(6), BONE(6), ATWO(6), BTWO(6), D3(7), D4(7)
      DATA AONE /0.112,0.130,0.112,0.098,0.0609,0.0638/
      DATA BONE /1.06,0.950,0.920,0.889,0.895,0.783/
      DATA ATWO /5.38E-4,6.52E-4,9.05E-4,1.35E-3,1.96E-3,
     *     1.36E-3/
      DATA BTWO /0.815,0.750,0.718,0.688,0.684,0.672/
      DATA D3 /0.20,0.12,0.08,0.06,0.03,0.016,0.016/
      DATA D4 /0.0,0.0,0.0002,0.0015,0.0003,0.0003,0.0003/
      P = 0.0
      NTYPE = JSTAB
      IF (NTYPE.GT.6) NTYPE = 6
      DO 10 I=1,50
           IKP = I
           IF (XM(I).GT.DIS) GO TO 20
   10 CONTINUE
   20 IF (IKP.LT.2) IKP = 2
      IKPM = IKP - 1
      IF (KDISP.GT.1) GO TO 40
C PASQUILL-GIFFORD DISPERSION VALUES
      DO 30 I=1,IKPM
           IKP = I + 1
           IF (SIGTAB(NTYPE,I).GT.SIGMAX(NTYPE)) GO TO 70
   30 CONTINUE
      P = ALOG(SIGTAB(NTYPE,IKP)/SIGTAB(NTYPE,IKPM))/
     *     ALOG(XM(IKP)/XM(IKPM))
      A = SIGTAB(NTYPE,IKP)/XM(IKP)**P
      SIGMA = A*DIS**P
      GO TO 60
C HOSKER'S FORMULATION OF BRIGGS-SMITH DISPERSION VALUES
   40 IF (KDISP.EQ.3) GO TO 50
      G = AONE(NTYPE)*DIS**BONE(NTYPE)/(1.0+ATWO(NTYPE)*DIS**
     *     BTWO(NTYPE))
      CALL FFAC(ROUGH, DIS, F)
      SIGMA = G*F
      GO TO 60
C BRIGGS DISPERSION VALUES
   50 SIGMA = D3(NTYPE)*DIS/SQRT(1.0+D4(NTYPE)*DIS)
   60 IF (SIGMA.LT.SIGMAX(NTYPE)) GO TO 80
   70 SIGMA = SIGMAX(NTYPE)
   80 IF (SIGMA.LT.1.0) SIGMA = 1.0
      RETURN
      END
```

```
      SUBROUTINE SIMPUN(XX, FX, NX, I, AX)
C PROGRAM AUTHOR       J. BARISH,
C COMPUTING TECHNOLOGY CENTER, UNION CARBIDE CORP., NUCLEAR DIV.,
C OAK RIDGE, TENN.
C
      DIMENSION XX(2), FX(2), AX(2)
      IF (I.LT.0) GO TO 30
      AX(1) = 0.0
      DO 10 IX=2,NX,2
        D1 = XX(IX) - XX(IX-1)
        AX(IX) = AX(IX-1) + D1/2.0*(FX(IX)+FX(IX-1))
        IF (NX.EQ.IX) GO TO 20
        D2 = XX(IX+1) - XX(IX-1)
        D3 = D2/D1
        A2 = D3/6.0*D2**2/(XX(IX+1)-XX(IX))
        A3 = D2/2.0 - A2/D3
        AX(IX+1) = AX(IX-1) + (D2-A2-A3)*FX(IX-1) + A2*FX(IX) +
     *       A3*FX(IX+1)
   10 CONTINUE
   20 RETURN
   30 AX(NX) = 0.0
      DO 40 IX=2,NX,2
        IC = NX + 1 - IX
        D1 = XX(IC+1) - XX(IC)
        AX(IC) = AX(IC+1) + D1/2.0*(FX(IC+1)+FX(IC))
        IF (NX.EQ.IX) GO TO 20
        D2 = XX(IC+1) - XX(IC-1)
        D3 = D2/(XX(IC)-XX(IC-1))
        A2 = D3/6.0*D2**2/D1
        A3 = D2/2.0 - A2/D3
        AX(IC-1) = AX(IC+1) + (D2-A2-A3)*FX(IC-1) + A2*FX(IC) +
     *       A3*FX(IC+1)
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WASH(IPTYPE, DF1, DF2, GRATE)
      LOGICAL SKIPP, SKIPA, SKIPL, SKIPG, SKIPOL
      DIMENSION IPTYPE(20), DF1(20), DF2(20)
      DIMENSION GRATE(40,12), A(7), B(7), A2RHO(7)
      COMMON /C1/ XM(50), SIGTAB(6,50), SIGMAX(6), V(20), DV(20),
     •    CLAMDA(20), DLAMDA(40,12,20), NDIST, NSTAB
      COMMON /C8/ NG, NP, NA, NL, NWS, NPOL, NFSTAB, NWINDS, WW, WF,
     •    FDRY(12)
      COMMON /C15/ SKIPP(10), SKIPA(10), SKIPL(10), SKIPG(40),
     •    SKIPOL(20)
      COMMON /C16/ KSEA
      DATA A /0.0,0.09549,0.034507,0.0239916,8.11996E-03,9.59721E-03,
     •    0.0104141/
      DATA B /0.333333,0.8405,0.493444,0.305593,0.321280,0.281789,
     •    0.249265/
      DATA A2RHO /4.0,7.8,16.0,41.0,81.0,169.0,400.0/, AA /5.546E-4/,
     •    PP /0.604229/
      DO 160 M=1,NPOL
         IF (SKIPOL(M)) GO TO 160
         IF (IPTYPE(M).EQ.2) GO TO 130
         ITAG = 0
C THE THREE INITIALIZATIONS TO FOLLOW ARE
C NECESSARY DUE TO FORTRAN OPTIMIZATION TECHNIQUES
         IKP = 1
         IKPP = 2
         FAC = 0.0
         ASR = DF1(M)**2*DF2(M)/4.
         IF (A2RHO(1).GE.ASR) GO TO 10
         GO TO 20
   10    ITAG = 1
         FAC = ASR/A2RHO(1)
         GO TO 30
   20    IF (ASR.LE.A2RHO(7)) GO TO 30
         ITAG = 2
   30    CONTINUE
         IF (ITAG.NE.0) GO TO 60
         DO 40 ITEST=1,6
            IKP = ITEST
            IKPP = IKP + 1
            IF (ASR.GT.A2RHO(ITEST) .AND. ASR.LE.A2RHO(IKPP)) GO TO 50
   40    CONTINUE
   50    CONTINUE
         FAC = (ASR-A2RHO(IKP))/(A2RHO(IKPP)-A2RHO(IKP))
   60    CONTINUE
         DO 120 I=1,NG
            IF (SKIPG(I)) GO TO 120
            DO 110 MON=1,KSEA
               X = GRATE(I,MON)*0.254
               IF (ITAG.NE.1) GO TO 70
               Y = FAC*(B(1)*X)
               DLAMDA(I,MON,M) = 1.0E-04*Y
               GO TO 110
   70          IF (ITAG.NE.2) GO TO 80
               Y = (-B(7)+SQRT(B(7)**2+4.*A(7)*X))/(2.*A(7))
               DLAMDA(I,MON,M) = 1.0E-04*Y
               GO TO 110
   80          CONTINUE
               IF (IKP.EQ.1) GO TO 90
               Y1 = (-B(IKP)+SQRT(B(IKP)**2+4.*A(IKP)*X))/(2.*A(IKP))
               GO TO 100
```

```
 90           Y1 = B(1)*X                                                WAS  610
100           Y2 = (-B(IKPP)+SQRT(B(IKPP)**2+4.*A(IKPP)*X))/(2.*          WAS  620
   *              A(IKPP))                                               WAS  630
              Y = Y1*(1.-FAC) + Y2*FAC                                   WAS  640
              DLAMDA(I,MON,M) = 1.0E-04*Y                                WAS  650
110        CONTINUE                                                      WAS  660
120     CONTINUE                                                         WAS  670
        GO TO 160                                                        WAS  680
130     CONTINUE                                                         WAS  690
        DF2M = DF2(M)*10000.0                                            WAS  700
        DO 150 I=1,NG                                                    WAS  710
           IF (SKIPG(I)) GO TO 150                                       WAS  720
           DO 140 MON=1,KSEA                                             WAS  730
              X = GRATE(I,MON)*0.254                                     WAS  740
              Y = AA*X**PP                                               WAS  750
              DLAMDA(I,MON,M) = Y*DF2M                                   WAS  760
140        CONTINUE                                                      WAS  770
150     CONTINUE                                                         WAS  780
160  CONTINUE                                                            WAS  790
     RETURN                                                              WAS  800
     END                                                                 WAS  810
```

```
      SUBROUTINE WNDSCE(WINDS)
      REAL MU
      DIMENSION WINDS(8), C(3)
      COMMON /C8/ NG, NP, NA, NL, NWS, NPOL, NFSTAB, NWINDS, WW, WF,
     *     FDRY(12)
      COMMON /C12/ WQIO(3,5,8), VFALL(3)
      COMMON /C19/ CONCF(3,5), SSCON(3), DEN(3), DSALT(3), DSUSP(3),
     *     ITYPE(3)
      DATA MU /182.7E-4/,G/9.8/,A/0.1/,RHO/1.213E+3/,Z/1.0/,RK/1.E-2/,C
     *     /1.5,1.8,2.8/
C ***  DSALT=AVERAGE DIAMETER(IN METERS) FOR SALTATING PARTICLES
C ***  DSUSP=AVERAGE DIAMETER(IN METERS) FOR SUSPENDED PARTICLES
C ***  WQIO(I,J,K)=EMISSION RATE IN GM/METER**2/SEC OF POLLUTANT J FROM
C ***  WINDBLOWN SOURCE I DURING TIME OF WINDSPEED CLASS K
C ***  CONCF(I,J)=CONCENTRATION FACTOR  FOR POLLUTANT J FROM WIND-
C ***  BLOWN SOURCE I
C ***  FDRY=FRACTION OF TIME WINDBLOWN SOURCE IS DRY
C ***  A=SAND PARTICLE THRESHOLD VELOCITY PROPORTIONALITY CONSTANT(0.1)
C ***  RHO=DENSITY OF AIR= 1.213E+3 GM/ M**3 AT 18C
C ***  Z=HEIGHT FOR WIND SPEED MEASUREMENT(USUALLY TAKEN AS 1 M)
C ***  RK=SURFACE ROUGHNESS(USUALLY TAKEN AS .01M)
C ***  G=GRAVITATIONAL ACCELERATION IN M/SEC**2
C ***  ITYPE=1---NEARLY UNIFORM SAND, C=1.5
C ***  ITYPE=2---NATURALLY GRADED SAND, C=1.8
C ***  ITYPE=3---WIDE RANGE OF GRAIN SIZE, C=2.8
C ***  DEN=DENSITY OF WINDBLOWN MATERIAL
C ***  MU=DYNAMIC VISCOSITY OF AIR(G/M/SEC)=182.7E-4 AT 18C
      IN = 5
      KOUT = 6
      GMU = G/(18.0*MU)
C ***  CALCULATE SETTLING VELOCITIES FOR SUSPENDED PARTICLES
      DO 10 I=1,NWS
        VFALL(I) = DSUSP(I)**2*GMU*DEN(I)*1.0E6
        WRITE (KOUT,99999) I, VFALL(I)
   10 CONTINUE
      ALPHA = 1./(5.75*ALOG10(Z/RK))**3
      DSTAND = 0.00025
      BETA = ALPHA*RHO/G
      DO 60 I=1,NWS
        WRITE (KOUT,99998) I
        VT =5.75*A*SQRT(((DEN(I)*1.E6-RHO)/RHO)*G*DSALT(I))*ALOG10(Z/RK)
        IITY = ITYPE(I)
        CS = C(IITY)
        BETACS = BETA*CS*SQRT(DSALT(I)/DSTAND)
        DO 50 JJ=1,NWINDS
          VR = WINDS(JJ)
          IF (VR.LT.VT) GO TO 20
          QST = BETACS*(VR-VT)**3
          GO TO 30
   20     QST = 0.
   30     CONTINUE
          DO 40 J=1,NPOL
            WQIO(I,J,JJ) = SSCON(I)*CONCF(I,J)*QST
            WRITE (KOUT,99997) J, JJ, WQIO(I,J,JJ)
   40     CONTINUE
   50   CONTINUE
   60 CONTINUE
      RETURN
99999 FORMAT (/10X, 40HDEPOSITION VELOCITY FOR WINDBLOWN SOURCE, I4,
     *     2X, 1H=, E12.4, 2X, 10HMETERS/SEC)
99998 FORMAT (///10X, 35HEMISSION DATA FROM WINDBLOWN SOURCE, I4/)
99997 FORMAT (10X, 9HPOLLUTANT, I4, 2X, 4HWIND, I4, 2X, 6HSOURCE,
     *     10H STRENGTH=, E12.4, 2X, 11HGM/M**2/SEC)
      END
```

APPENDIX C

GLOSSARY OF TERMS USED IN THE ATM-TOX COMPUTER PROGRAM

APPENDIX C

GLOSSARY OF TERMS USED IN THE ATM-TOX COMPUTER PROGRAM

A	Sand particle threshold velocity property constant (0.1)
F(32,40,10)	Fraction of sector occupied by transformed area segment
G	Gravity (9.8m/s^2)
H	Height corrected for plume rise (m)
R	Earth's radius (m)
V(20)	Terminal velocity (m/s)
Z	Height for wind-speed measurement (m)
AT(10)	Air temperature (K)
DA(40,10)	Distance from gage to area-source centroid (m)
DL	Distance from gage to middle of line source (m)
DP(40,10)	Distance from gage to point source (m)
DV(5)	Deposition velocity (m/s)
MU	Viscosity of air at 18°C
NA(10)	# of area sources
NG(40)	# of rain gages
NL(10)	# of line sources
NP(10)	# of point sources
RK	Surface roughness (m)
R1(40,10)	Radial values for transformation of area sources
R2(40,10)	Radial values for transformation of area sources
ST(10)	Stack gas temperature (K)
WF	Fraction of time during which only fallout occurs
WW	Fraction of time during which both washout and fallout occur
XM(50)	Distances for stability data (m)
DEN(3)	Density of windblown material (g/m^3)
DF1(20)	Diameter of particle (microns)
DF2(20)	Density of particle (g/cm^3)
DTH(40,10)	Angle for transformation of area sources
HGA(10)	Height of area sources (m)
HGL(10)	Height of line sources (m)
HGT(10)	Height of point sources (m)
HTA(12)	Climatological mean value of afternoon mixing height (m)
HTG(40)	Height of gage above base level (m)
HTN(12)	Climatological mean value of nocturnal mixing height (m)
NBG	Switch for background concentrations
NWS	# of wind blown area sources (maximum of 3)
PI8	Pi/8.0
QQP	Subroutine
RAD(10)	Radius of stack (m) for point source
RHO	Density of air (g/m^3)
TH1(40,10)	Angles for transformation of area sources
TH2(40,10)	Angles for transformation of area sources
VEL(10)	Stack gas ejection velocity (m/s)
APHI(10)	Longitude of area-source centroids (radians)
AQI0(10,20,12)	Emission rate of area sources (g/m^2-s)
AREA(10)	Area of area sources (m^2)

ATHA(10)	Latitude of area-source centroids (radians)
COMP(32)	Used in transformation of area sources
COPA	Air concentration from area sources (g/m^3)
COPL	Air concentration from line sources (g/m^3)
COPP	Air concentration from point sources (g/m^3)
COPT	Air concentration from all sources (g/m^3)
DCAL	Subroutine
DEPA(40,20,12)	Area-source deposition rate (g/m^2-s)
DEPL(40,20,12)	Line-source deposition rate (g/m^2-s)
DEPP(40,20,12)	Point-source deposition rate (g/m^2-s)
DEPT(40,20,12)	Total source deposition rate (g/m^2-s)
DIRA(40,10)	Direction from gage to area-source centroid (degrees)
DIRP(40,10)	Direction from gage to point source (degrees)
FALL	Subroutine
FDRY(12)	Fraction of time windblown source is dry
FFAC	Subroutine
FREQ(12,7,8,16)	Wind frequency table
GPHI(40)	Longitude of gages (radians)
GTHA(40)	Latitude of gages (radians)
HMIX(8,12)	Mixing height as a function of stability class (m)
IPAR	# of parent pollutant
ICHO	Switch for MAXCON (if ICHO = 2)
KSEA	No. of seasons (or months) of wind data
KTAG	Switch for print statement on wind frequency
LQI0(10,20,12)	Emission rate of line sources (g/m/-s)
NDIR	# of directions in wind frequency table (usually 16)
NPOL	# of pollutants (maximum of 5)
PPHI(10)	Longitude of point sources (radians)
PQI0(10,20,12)	Emission rate of point sources (g/s)
PTHA(10)	Latitude of point sources (radians)
SIGA	Subroutine
SURF(40)	KCOVER for each gage
WASH	Subroutine
WQI0(3,5,8)	Windblown source strength (g/m^2-s)

ALATD(10)	Latitude of area source (degrees)
ALATM(10)	Latitude of area source (minutes)
ALATS(10)	Latitude of area source (seconds)
ALOND(10)	Longitude of area source (degrees)
ALONM(10)	Longitude of area source (minutes)
ALONS(10)	Longitude of area source (seconds)
ANAME(10)	Names of area sources
CONCF(3,5)	Concentration factor for windblown source
DSALT(3)	Saltation diameter (m)
DSUSP(3)	Suspension diameter (m)
FRACT(12)	Fraction of the month in which precipitation occurs
GLATD(40)	Latitude of gage (degrees)
GLATM(40)	Latitude of gage (minutes)
GLATS(40)	Latitude of gage (seconds)
GLOND(40)	Longitude of gage (degrees)
GLONM(40)	Longitude of gage (minutes)
GLONS(40)	Longitude of gage (seconds)
GNAME(40)	Names of gages

GRATE(40,12)	Average rate of precipitation for each gage (hundredths of an inch/hr)
ITYPE(3)	Type of windblown source
JSTAB(7)	Index of stabilities to be used
KDISP	Stability switch (1 for Pasquill-Gifford, 2 for Briggs-Smith, 3 for Briggs)
LFPHI(10)	Longitude of line-source end (radians)
LFTHA(10)	Latitude of line-source end (radians)
LNAME(10)	Names of line sources
LSPHI(10)	Longitude of line-source start (radians)
LSTHA(10)	Latitude of line-source start (radians)
NDIST	# of distances in stability table
NSTAB	# of stabilities in frequency table
PI180	Pi/180.0
PLATD(10)	Latitude of point source (degrees)
PLATM(10)	Latitude of point source (minutes)
PLATS(10)	Latitude of point source (seconds)
PLOND(10)	Longitude of point source (degrees)
PLONM(10)	Longitude of point source (minutes)
PLONS(10)	Longitude of point source (seconds)
PLUME	Subroutine
PNAME(10)	Names of point sources
ROUGH	Roughness of land surface (m)
SIGMA	Subroutine
SKIPA(10)	Switch for area sources (T=not used, F=used)
SKIPG(40)	Switch for gages (T=not used, F=used)
SKIPL(10)	Switch for line sources (T=not used, F=used)
SKIPP(10)	Switch for point sources (T=not used, F=used)
SSCON(3)	Suspension to saltation ratio for windblown source
THALF(20)	Half-life for pollutant (seconds)
VFALL(3)	Deposition velocity for windblown source (m/s)
WINDS(8)	Wind speeds at ground level (10m)
ATITLE(10)	Title for study
AVRATE(12)	Average rate of precipitation (hundredths of an inch/hr)
CLAMDA(5)	Washout rate of pollutant (s^{-1})
DLAMDA(40,12,20)	Washout rate for each pollutant for each gage (s^{-1})
DRYDEP(40,20,12)	Dry deposition (g/m^2-s)
E02AEF	Subroutine from NAG library
E02CBF	Subroutine from NAG library
FRXTRN	Subroutine
GEOMET	Subroutine
GFRACT(40,12)	Fract. of month for which precipitation occurs for each gage
IPTYPE(20)	Type of pollutant (1 for particulate, 2 for gas)
KCOVER	Type of cover (<5 for grass, >5 for forest)
KDUMMY	Dummy read for title of wind data set
LLATDF(10)	Latitude of line-source end (degrees)
LLATDS(10)	Latitude of line-source start (degrees)
LLATMF(10)	Latitude of line-source end (minutes)
LLATMS(10)	Latitude of line-source start (minutes)
LLATSF(10)	Latitude of line-source end (seconds)
LLATSS(10)	Latitude of line-source start (seconds)
LLONDF(10)	Longitude of line-source end (degrees)

LLONDS(10)	Longitude of line-source start (degrees)
LLONMF(10)	Longitude of line-source end (minutes)
LLONMS(10)	Longitude of line-source start (minutes)
LLONSF(10)	Longitude of line-source end (seconds)
LLONSS(10)	Longitude of line-source start (seconds)
MAXCON	Subroutine
NFSTAB	# of stabilities in frequency table
NWINDS	# of winds in frequency table
P01AAF	Function from NAG library
PKAPPA	Plume-rise parameter for stabilities 1-4
POLNAM(20)	Name of pollutant
PURBAN(7)	Exponents for wind profile (urban sigmas)
PRURAL(7)	Exponents for wind profile (rural sigmas)
QKAPPA	Plume-rise parameter for stabilities 5-6
SEANAM(12)	Names of seasons (or months)
SIGMAX(7)	Maximum value of vertical dispersion for each stability (m)
SIGTAB(6,50)	Pasquill stabilities
SIMPUN	Subroutine
SKIPOL(20)	Switch for pollutant (T=not used, F=used)
STNFRD	Name of recording station
WETDEP(40,20,12)	Wet deposition (g/m^2-s)
WINDSD(8,7,10)	Wind speed at height of point source for each stability class (m/s)
WNDSCE	Subroutine
X02AAF	Function from NAG library
X04AAF	Subroutine from NAG library

APPENDIX D

INPUT DATA SET

```
   TEST RUN WITH POINT,AREA AND LINE SOURCES
 2    1    1  0.15
600.
400.
 6   16      6    1     2    3     4    5     6
 0.90       2.57       4.37       6.94       9.77   12.35
ANNUAL
   KNOXVILLE, TN, WINDROSE, ANNUAL, 6 STABILITIES
  N A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
NNE A 0.0008 0.0002 0.0000 0.0000 0.0000 0.0000
 NE A 0.0008 0.0002 0.0000 0.0000 0.0000 0.0000
ENE A 0.0008 0.0002 0.0000 0.0000 0.0000 0.0000
  E A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
ESE A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 SE A 0.0008 0.0002 0.0000 0.0000 0.0000 0.0000
SSE A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
  S A 0.0008 0.0002 0.0000 0.0000 0.0000 0.0000
SSW A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
 SW A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
WSW A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
  W A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
WNW A 0.0008 0.0002 0.0000 0.0000 0.0000 0.0000
 NW A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
NNW A 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
  N B 0.0019 0.0062 0.0016 0.0000 0.0000 0.0000
NNE B 0.0023 0.0053 0.0007 0.0000 0.0000 0.0000
 NE B 0.0020 0.0069 0.0014 0.0000 0.0000 0.0000
ENE B 0.0020 0.0034 0.0007 0.0000 0.0000 0.0000
  E B 0.0011 0.0014 0.0009 0.0000 0.0000 0.0000
ESE B 0.0011 0.0021 0.0005 0.0000 0.0000 0.0000
 SE B 0.0010 0.0005 0.0000 0.0000 0.0000 0.0000
SSE B 0.0008 0.0007 0.0000 0.0000 0.0000 0.0000
  S B 0.0011 0.0018 0.0000 0.0000 0.0000 0.0000
SSW B 0.0004 0.0016 0.0002 0.0000 0.0000 0.0000
 SW B 0.0009 0.0025 0.0007 0.0000 0.0000 0.0000
WSW B 0.0009 0.0021 0.0007 0.0000 0.0000 0.0000
  W B 0.0010 0.0030 0.0009 0.0000 0.0000 0.0000
WNW B 0.0011 0.0023 0.0007 0.0000 0.0000 0.0000
 NW B 0.0004 0.0025 0.0002 0.0000 0.0000 0.0000
NNW B 0.0009 0.0023 0.0005 0.0000 0.0000 0.0000
  N C 0.0005 0.0069 0.0034 0.0000 0.0000 0.0000
NNE C 0.0007 0.0057 0.0046 0.0000 0.0000 0.0000
 NE C 0.0007 0.0066 0.0062 0.0000 0.0000 0.0000
ENE C 0.0002 0.0050 0.0023 0.0000 0.0000 0.0000
  E C 0.0009 0.0041 0.0021 0.0000 0.0000 0.0000
ESE C 0.0005 0.0016 0.0011 0.0000 0.0000 0.0000
 SE C 0.0007 0.0009 0.0002 0.0000 0.0000 0.0000
SSE C 0.0000 0.0009 0.0000 0.0000 0.0000 0.0000
  S C 0.0006 0.0018 0.0009 0.0000 0.0000 0.0000
SSW C 0.0001 0.0014 0.0014 0.0002 0.0000 0.0000
 SW C 0.0001 0.0018 0.0030 0.0002 0.0000 0.0000
WSW C 0.0002 0.0046 0.0053 0.0000 0.0000 0.0000
  W C 0.0003 0.0071 0.0046 0.0002 0.0000 0.0000
WNW C 0.0003 0.0025 0.0021 0.0000 0.0000 0.0000
 NW C 0.0003 0.0021 0.0016 0.0000 0.0000 0.0000
NNW C 0.0004 0.0034 0.0009 0.0000 0.0000 0.0000
  N D 0.0044 0.0201 0.0188 0.0064 0.0000 0.0000
NNE D 0.0046 0.0183 0.0137 0.0023 0.0000 0.0000
 NE D 0.0041 0.0176 0.0199 0.0034 0.0000 0.0000
ENE D 0.0028 0.0098 0.0105 0.0027 0.0000 0.0000
  E D 0.0034 0.0062 0.0039 0.0009 0.0000 0.0000
ESE D 0.0019 0.0032 0.0027 0.0002 0.0000 0.0000
```

```
 SE D 0.0016 0.0023 0.0011 0.0009 0.0000 0.0000
SSE D 0.0008 0.0016 0.0009 0.0005 0.0000 0.0000
  S D 0.0025 0.0048 0.0030 0.0025 0.0000 0.0000
SSW D 0.0014 0.0039 0.0039 0.0025 0.0007 0.0000
 SW D 0.0017 0.0082 0.0108 0.0069 0.0016 0.0000
WSW D 0.0024 0.0121 0.0153 0.0117 0.0011 0.0000
  W D 0.0033 0.0153 0.0167 0.0110 0.0009 0.0000
WNW D 0.0021 0.0092 0.0085 0.0048 0.0002 0.0000
 NW D 0.0013 0.0057 0.0055 0.0016 0.0002 0.0000
NNW D 0.0028 0.0103 0.0032 0.0005 0.0000 0.0000
  N E 0.0000 0.0105 0.0062 0.0000 0.0000 0.0000
NNE E 0.0000 0.0098 0.0060 0.0000 0.0000 0.0000
 NE E 0.0000 0.0195 0.0055 0.0000 0.0000 0.0000
ENE E 0.0000 0.0140 0.0032 0.0000 0.0000 0.0000
  E E 0.0000 0.0073 0.0002 0.0000 0.0000 0.0000
ESE E 0.0000 0.0053 0.0005 0.0000 0.0000 0.0000
 SE E 0.0000 0.0030 0.0000 0.0000 0.0000 0.0000
SSE E 0.0000 0.0021 0.0000 0.0000 0.0000 0.0000
  S E 0.0000 0.0050 0.0009 0.0000 0.0000 0.0000
SSW E 0.0000 0.0053 0.0007 0.0000 0.0000 0.0000
 SW E 0.0000 0.0062 0.0025 0.0000 0.0000 0.0000
WSW E 0.0000 0.0119 0.0016 0.0000 0.0000 0.0000
  W E 0.0000 0.0071 0.0021 0.0000 0.0000 0.0000
WNW E 0.0000 0.0037 0.0007 0.0000 0.0000 0.0000
 NW E 0.0000 0.0025 0.0000 0.0000 0.0000 0.0000
NNW E 0.0000 0.0041 0.0000 0.0000 0.0000 0.0000
  N F 0.0074 0.0114 0.0000 0.0000 0.0000 0.0000
NNE F 0.0100 0.0158 0.0000 0.0000 0.0000 0.0000
 NE F 0.0181 0.0238 0.0000 0.0000 0.0000 0.0000
ENE F 0.0179 0.0163 0.0000 0.0000 0.0000 0.0000
  E F 0.0140 0.0085 0.0000 0.0000 0.0000 0.0000
ESE F 0.0124 0.0055 0.0000 0.0000 0.0000 0.0000
 SE F 0.0082 0.0048 0.0000 0.0000 0.0000 0.0000
SSE F 0.0034 0.0030 0.0000 0.0000 0.0000 0.0000
  S F 0.0086 0.0055 0.0000 0.0000 0.0000 0.0000
SSW F 0.0052 0.0060 0.0000 0.0000 0.0000 0.0000
 SW F 0.0066 0.0060 0.0000 0.0000 0.0000 0.0000
WSW F 0.0106 0.0101 0.0000 0.0000 0.0000 0.0000
  W F 0.0090 0.0073 0.0000 0.0000 0.0000 0.0000
WNW F 0.0052 0.0021 0.0000 0.0000 0.0000 0.0000
 NW F 0.0027 0.0025 0.0000 0.0000 0.0000 0.0000
NNW F 0.0070 0.0034 0.0000 0.0000 0.0000 0.0000
    4     1     2     1     1
    F     F     F     F
    F
    F     F
    F
 36.00000   0.00000   0.00000  83.00000  59.00000  19.95644              GAGE  1
 36.00000   0.00000  32.39592  84.00000   0.00000   0.00000              GAGE  2
 36.00000   0.00000   0.00000  84.00000   0.00000  40.04356              GAGE  3
 35.00000  59.00000  27.60408  84.00000   0.00000   0.00000              GAGE  4
 36.       00.0       0.0      84.         0.0       0.0       80.0      POINT 1
 36.       00.0       0.0      84.         0.0       0.0        1.0      AREA 1
 36.       10.0       0.0      84.         0.0       0.0        1.0      AREA 2
 36.       00.0       1.6229   84.         0.0       0.0        1.0      LINE 1
 35.       59.0      58.3771   84.         0.0       0.0
1.000E+02 2.000E+01
350.
280.
 1.5
10.0
```

```
    1  1.0
    F
    2  0.01      0.00001
  1.0
 1.000E-02 2.000E+02
 1.000E-02
          1 1.000E+06 1.000E-03 1.000E-03
 0.5
 0.75
 0.1
    1
```

APPENDIX E

JOB CONTROL LANGUAGE

```
/33
//RJRZATM JOB (21913,IO5),' SAVE6137,72RJR-A226',TIME=5
// EXEC FORTDCLG,PARM.FORT='OPT=2,XREF,ID,MAP,DUMP=-G',
// REGION.FORT=270K,
// PARM.GO='EU=-1,DUMP=H,SI=50,SO=51,SP=52,',
// REGION.GO=720K,TIME.GO=5
//FORT.SYSIN DD *
=ATM.F4
/*
//GO.FT07F001 DD SYSOUT=B,DCB=(RECFM=FB,LRECL=80,BLKSIZE=3520)
//GO.FT06F001 DD SYSOUT=A
//GO.FT05F001 DD *
=ATM.DAT
/*ROUTE  PRINT LOCAL
/*ROUTE  PUNCH RMT45
//
ENDINPUT
```

APPENDIX F

OUTPUT FROM PROGRAM

TEST RUN WITH POINT,AREA AND LINE SOURCES

PASQUILL STABILITIES NOT USED—STABILITIES FOUND IN SUBROUTINE SIGMA

FORMULATION BY HOSKER OF BRIGGS-SMITH DISPERSION VALUES

DISPERSION COEFFICIENTS FOR STABILITY CLASS

X(M)	A	B	C	D	E	F
1.0	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01
2.0	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01
3.0	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01
4.0	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01
5.0	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01	0.1000E+01
10.0	0.1411E+01	0.1271E+01	0.1021E+01	0.1000E+01	0.1000E+01	0.1000E+01
15.0	0.2165E+01	0.1865E+01	0.1480E+01	0.1188E+01	0.1000E+01	0.1000E+01
20.0	0.2933E+01	0.2449E+01	0.1925E+01	0.1531E+01	0.1000E+01	0.1000E+01
25.0	0.3711E+01	0.3023E+01	0.2361E+01	0.1863E+01	0.1174E+01	0.1000E+01
30.0	0.4497E+01	0.3591E+01	0.2788E+01	0.2188E+01	0.1379E+01	0.1000E+01
35.0	0.5289E+01	0.4154E+01	0.3209E+01	0.2505E+01	0.1580E+01	0.1120E+01
40.0	0.6086E+01	0.4711E+01	0.3625E+01	0.2817E+01	0.1777E+01	0.1241E+01
45.0	0.6888E+01	0.5263E+01	0.4035E+01	0.3123E+01	0.1970E+01	0.1360E+01
50.0	0.7694E+01	0.5812E+01	0.4441E+01	0.3425E+01	0.2161E+01	0.1475E+01
100.0	0.1589E+02	0.1114E+02	0.8324E+01	0.6269E+01	0.3953E+01	0.2510E+01
200.0	0.3254E+02	0.2121E+02	0.1550E+02	0.1138E+02	0.7155E+01	0.4242E+01
300.0	0.4891E+02	0.3058E+02	0.2205E+02	0.1595E+02	0.9990E+01	0.5703E+01
400.0	0.6497E+02	0.3948E+02	0.2819E+02	0.2017E+02	0.1259E+02	0.7005E+01
500.0	0.8073E+02	0.4802E+02	0.3403E+02	0.2414E+02	0.1502E+02	0.8198E+01
600.0	0.9623E+02	0.5628E+02	0.3964E+02	0.2792E+02	0.1731E+02	0.9309E+01
700.0	0.1115E+03	0.6429E+02	0.4505E+02	0.3153E+02	0.1949E+02	0.1035E+02
800.0	0.1265E+03	0.7209E+02	0.5028E+02	0.3499E+02	0.2158E+02	0.1134E+02
900.0	0.1412E+03	0.7969E+02	0.5536E+02	0.3834E+02	0.2359E+02	0.1229E+02
1000.0	0.1558E+03	0.8713E+02	0.6031E+02	0.4159E+02	0.2552E+02	0.1319E+02
1100.0	0.1701E+03	0.9441E+02	0.6514E+02	0.4474E+02	0.2738E+02	0.1406E+02
1200.0	0.1842E+03	0.1016E+03	0.6985E+02	0.4780E+02	0.2919E+02	0.1490E+02
1300.0	0.1981E+03	0.1086E+03	0.7447E+02	0.5078E+02	0.3094E+02	0.1571E+02
1400.0	0.2118E+03	0.1154E+03	0.7899E+02	0.5370E+02	0.3264E+02	0.1650E+02
1600.0	0.2387E+03	0.1289E+03	0.8777E+02	0.5932E+02	0.3592E+02	0.1800E+02
1800.0	0.2648E+03	0.1419E+03	0.9625E+02	0.6472E+02	0.3904E+02	0.1943E+02
2000.0	0.2904E+03	0.1545E+03	0.1044E+03	0.6991E+02	0.4202E+02	0.2079E+02
2500.0	0.3515E+03	0.1846E+03	0.1239E+03	0.8211E+02	0.4895E+02	0.2393E+02
3000.0	0.4093E+03	0.2129E+03	0.1421E+03	0.9341E+02	0.5529E+02	0.2679E+02
3500.0	0.4641E+03	0.2398E+03	0.1592E+03	0.1040E+03	0.6115E+02	0.2942E+02
4000.0	0.5162E+03	0.2653E+03	0.1754E+03	0.1139E+03	0.6660E+02	0.3186E+02
4500.0	0.5659E+03	0.2896E+03	0.1908E+03	0.1233E+03	0.7170E+02	0.3414E+02
5000.0	0.6134E+03	0.3130E+03	0.2055E+03	0.1322E+03	0.7652E+02	0.3629E+02
6000.0	0.7027E+03	0.3569E+03	0.2332E+03	0.1488E+03	0.8540E+02	0.4025E+02
7000.0	0.7852E+03	0.3977E+03	0.2588E+03	0.1640E+03	0.9345E+02	0.4383E+02
8000.0	0.8620E+03	0.4358E+03	0.2826E+03	0.1781E+03	0.1008E+03	0.4710E+02
10000.0	0.1001E+04	0.5055E+03	0.3260E+03	0.2036E+03	0.1140E+03	0.5293E+02
15000.0	0.1288E+04	0.6512E+03	0.4165E+03	0.2561E+03	0.1406E+03	0.6459E+02
20000.0	0.1517E+04	0.7691E+03	0.4894E+03	0.2981E+03	0.1614E+03	0.7361E+02
30000.0	0.1869E+04	0.9537E+03	0.6038E+03	0.3632E+03	0.1931E+03	0.8715E+02
40000.0	0.2138E+04	0.1096E+04	0.6921E+03	0.4132E+03	0.2000E+03	0.9715E+02
50000.0	0.2355E+04	0.1212E+04	0.7640E+03	0.4538E+03	0.2000E+03	0.1000E+03
60000.0	0.2537E+04	0.1309E+04	0.8000E+03	0.4880E+03	0.2000E+03	0.1000E+03
70000.0	0.2694E+04	0.1392E+04	0.8000E+03	0.5000E+03	0.2000E+03	0.1000E+03
80000.0	0.2832E+04	0.1466E+04	0.8000E+03	0.5000E+03	0.2000E+03	0.1000E+03
100000.0	0.3067E+04	0.1590E+04	0.8000E+03	0.5000E+03	0.2000E+03	0.1000E+03

ROUGHNESS= 0.150E 00 METERS

NUMBER OF WIND SPEEDS= 6
NUMBER OF WIND DIRECTIONS= 16
NUMBER OF WIND STABILITIES= 6
STABILITIES USED---- 1 2 3 4 5 6

SIGMAX FOR EACH STABILITY IN THE TABLE= 3200. 1600. 800. 500. 200. 100.

STABILITY WIND ROSE DATA FOR PERIOD 1 ANNUAL

STABILITY CLASS 1

DIRECTION 1	0.0	0.0	0.0	0.0	0.0	0.0
DIRECTION 2	0.000800	0.000200	0.0	0.0	0.0	0.0
DIRECTION 3	0.000800	0.000200	0.0	0.0	0.0	0.0
DIRECTION 4	0.000800	0.000200	0.0	0.0	0.0	0.0
DIRECTION 5	0.0	0.0	0.0	0.0	0.0	0.0
DIRECTION 6	0.0	0.0	0.0	0.0	0.0	0.0
DIRECTION 7	0.000800	0.000200	0.0	0.0	0.0	0.0
DIRECTION 8	0.0	0.0	0.0	0.0	0.0	0.0
DIRECTION 9	0.000800	0.000200	0.0	0.0	0.0	0.0
DIRECTION 10	0.0	0.0	0.0	0.0	0.0	0.0
DIRECTION 11	0.0	0.0	0.0	0.0	0.0	0.0
DIRECTION 12	0.0	0.0	0.0	0.0	0.0	0.0
DIRECTION 13	0.0	0.0	0.0	0.0	0.0	0.0
DIRECTION 14	0.000800	0.000200	0.0	0.0	0.0	0.0
DIRECTION 15	0.0	0.0	0.0	0.0	0.0	0.0
DIRECTION 16	0.0	0.0	0.0	0.0	0.0	0.0

STABILITY CLASS 2

DIRECTION 1	0.001901	0.006202	0.001600	0.0	0.0	0.0
DIRECTION 2	0.002301	0.005302	0.000700	0.0	0.0	0.0
DIRECTION 3	0.002001	0.006902	0.001400	0.0	0.0	0.0
DIRECTION 4	0.002001	0.003401	0.000700	0.0	0.0	0.0
DIRECTION 5	0.001100	0.001400	0.000900	0.0	0.0	0.0
DIRECTION 6	0.001100	0.002101	0.000500	0.0	0.0	0.0
DIRECTION 7	0.001000	0.000500	0.0	0.0	0.0	0.0
DIRECTION 8	0.000800	0.000700	0.0	0.0	0.0	0.0
DIRECTION 9	0.001100	0.001801	0.0	0.0	0.0	0.0
DIRECTION 10	0.000400	0.001600	0.000200	0.0	0.0	0.0
DIRECTION 11	0.000900	0.002501	0.000700	0.0	0.0	0.0
DIRECTION 12	0.000900	0.002101	0.000700	0.0	0.0	0.0
DIRECTION 13	0.001000	0.003001	0.000900	0.0	0.0	0.0
DIRECTION 14	0.001100	0.002301	0.000700	0.0	0.0	0.0
DIRECTION 15	0.000400	0.002501	0.000200	0.0	0.0	0.0
DIRECTION 16	0.000900	0.002301	0.000500	0.0	0.0	0.0

STABILITY CLASS 3

DIRECTION 1	0.000500	0.006902	0.003401	0.0	0.0	0.0
DIRECTION 2	0.000700	0.005702	0.004601	0.0	0.0	0.0
DIRECTION 3	0.000700	0.006602	0.006202	0.0	0.0	0.0
DIRECTION 4	0.000200	0.005002	0.002301	0.0	0.0	0.0
DIRECTION 5	0.000900	0.004101	0.002101	0.0	0.0	0.0
DIRECTION 6	0.000500	0.001600	0.001100	0.0	0.0	0.0
DIRECTION 7	0.000700	0.000900	0.000200	0.0	0.0	0.0
DIRECTION 8	0.0	0.000900	0.0	0.0	0.0	0.0
DIRECTION 9	0.000600	0.001801	0.000900	0.0	0.0	0.0
DIRECTION 10	0.000100	0.001400	0.001400	0.000200	0.0	0.0
DIRECTION 11	0.000100	0.001801	0.003001	0.000200	0.0	0.0
DIRECTION 12	0.000200	0.004601	0.005302	0.0	0.0	0.0
DIRECTION 13	0.000300	0.007102	0.004601	0.000200	0.0	0.0
DIRECTION 14	0.000300	0.002501	0.002101	0.0	0.0	0.0
DIRECTION 15	0.000300	0.002101	0.001600	0.0	0.0	0.0
DIRECTION 16	0.000400	0.003401	0.000900	0.0	0.0	0.0

			STABILITY CLASS		4	
DIRECTION 1	0.004401	0.020106	0.018806	0.006402	0.0	0.0
DIRECTION 2	0.004601	0.018306	0.013704	0.002301	0.0	0.0
DIRECTION 3	0.004101	0.017605	0.019906	0.003401	0.0	0.0
DIRECTION 4	0.002801	0.009803	0.010503	0.002701	0.0	0.0
DIRECTION 5	0.003401	0.006202	0.003901	0.000900	0.0	0.0
DIRECTION 6	0.001901	0.003201	0.002701	0.000200	0.0	0.0
DIRECTION 7	0.001600	0.002301	0.001100	0.000900	0.0	0.0
DIRECTION 8	0.000800	0.001600	0.000900	0.000500	0.0	0.0
DIRECTION 9	0.002501	0.004801	0.003001	0.002501	0.0	0.0
DIRECTION 10	0.001400	0.003901	0.003901	0.002501	0.000700	0.0
DIRECTION 11	0.001701	0.008202	0.010803	0.006902	0.001600	0.0
DIRECTION 12	0.002401	0.012104	0.015305	0.011704	0.001100	0.0
DIRECTION 13	0.003301	0.015305	0.016705	0.011003	0.000900	0.0
DIRECTION 14	0.002101	0.009203	0.008503	0.004801	0.000200	0.0
DIRECTION 15	0.001300	0.005702	0.005502	0.001600	0.000200	0.0
DIRECTION 16	0.002801	0.010303	0.003201	0.000500	0.0	0.0
			STABILITY CLASS		5	
DIRECTION 1	0.0	0.010503	0.006202	0.0	0.0	0.0
DIRECTION 2	0.0	0.009803	0.006002	0.0	0.0	0.0
DIRECTION 3	0.0	0.019506	0.005502	0.0	0.0	0.0
DIRECTION 4	0.0	0.014004	0.003201	0.0	0.0	0.0
DIRECTION 5	0.0	0.007302	0.000200	0.0	0.0	0.0
DIRECTION 6	0.0	0.005302	0.000500	0.0	0.0	0.0
DIRECTION 7	0.0	0.003001	0.0	0.0	0.0	0.0
DIRECTION 8	0.0	0.002101	0.0	0.0	0.0	0.0
DIRECTION 9	0.0	0.005002	0.000900	0.0	0.0	0.0
DIRECTION 10	0.0	0.005302	0.000700	0.0	0.0	0.0
DIRECTION 11	0.0	0.006202	0.002501	0.0	0.0	0.0
DIRECTION 12	0.0	0.011904	0.001600	0.0	0.0	0.0
DIRECTION 13	0.0	0.007102	0.002101	0.0	0.0	0.0
DIRECTION 14	0.0	0.003701	0.000700	0.0	0.0	0.0
DIRECTION 15	0.0	0.002501	0.0	0.0	0.0	0.0
DIRECTION 16	0.0	0.004101	0.0	0.0	0.0	0.0
			STABILITY CLASS		6	
DIRECTION 1	0.007402	0.011403	0.0	0.0	0.0	0.0
DIRECTION 2	0.010003	0.015805	0.0	0.0	0.0	0.0
DIRECTION 3	0.018106	0.023807	0.0	0.0	0.0	0.0
DIRECTION 4	0.017905	0.016305	0.0	0.0	0.0	0.0
DIRECTION 5	0.014004	0.008503	0.0	0.0	0.0	0.0
DIRECTION 6	0.012404	0.005502	0.0	0.0	0.0	0.0
DIRECTION 7	0.008202	0.004801	0.0	0.0	0.0	0.0
DIRECTION 8	0.003401	0.003001	0.0	0.0	0.0	0.0
DIRECTION 9	0.008603	0.005502	0.0	0.0	0.0	0.0
DIRECTION 10	0.005202	0.006002	0.0	0.0	0.0	0.0
DIRECTION 11	0.006602	0.006002	0.0	0.0	0.0	0.0
DIRECTION 12	0.010603	0.010103	0.0	0.0	0.0	0.0
DIRECTION 13	0.009003	0.007302	0.0	0.0	0.0	0.0
DIRECTION 14	0.005202	0.002101	0.0	0.0	0.0	0.0
DIRECTION 15	0.002701	0.002501	0.0	0.0	0.0	0.0
DIRECTION 16	0.007002	0.003401	0.0	0.0	0.0	0.0

LATITUDE, LONGITUDE AND HEIGHT OF GAUGE SAMPLING POINTS

ID NUMBER	NAME	LATITUDE DEGREES	MINUTES	SECONDS	LONGITUDE DEGREES	MINUTES	SECONDS	HEIGHT(M)
1	GAGE 1	36.00	0.0	0.0	83.00	59.00	19.96	0.0
2	GAGE 2	36.00	0.0	32.40	84.00	0.0	0.0	0.0
3	GAGE 3	36.00	0.0	0.0	84.00	0.0	40.04	0.0
4	GAGE 4	35.00	59.00	27.60	84.00	0.0	0.0	0.0

LATITUDE AND LONGITUDE OF POINT SOURCES

ID NUMBER	NAME	LATITUDE DEGREES	MINUTES	SECONDS	LONGITUDE DEGREES	MINUTES	SECONDS
1	POINT 1	36.00	0.0	0.0	84.00	0.0	0.0

LATITUDE, LONGITUDE AND HEIGHT OF AREA SOURCE CENTROIDS

ID NUMBER	NAME	LATITUDE DEGREES	MINUTES	SECONDS	LONGITUDE DEGREES	MINUTES	SECONDS	
1	AREA 1	36.00	0.0	0.0	84.00	0.0	0.0	1.0
2	AREA 2	36.00	10.00	0.0	84.00	0.0	0.0	1.0

LATITUDE, LONGITUDE AND HEIGHT OF LINE SOURCE ENDPOINTS

ID NUMBER	NAME	LATITUDE DEGREES	MINUTES	SECONDS	LONGITUDE DEGREES	MINUTES	SECONDS	
1	LINE 1	36.00	0.0	1.62	84.00	0.0	0.0	1.0
1	LINE 1	35.00	59.00	58.38	84.00	0.0	0.0	

AREA SOURCE AREAS IN METERS**2

AREA SOURCE 1 AREA 1 1.000E 02

AREA SOURCE 2 AREA 2 2.000E 01

DISTANCE IN METERS FROM GAUGE 1 TO POINT SOURCE 1 = 0.100E 04
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 1 TO POINT SOURCE 1 = 0.270E 03

DISTANCE IN METERS FROM GAUGE 2 TO POINT SOURCE 1 = 0.100E 04
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 2 TO POINT SOURCE 1 = 0.180E 03

DISTANCE IN METERS FROM GAUGE 3 TO POINT SOURCE 1 = 0.999E 03
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 3 TO POINT SOURCE 1 = 0.900E 02

DISTANCE IN METERS FROM GAUGE 4 TO POINT SOURCE 1 = 0.100E 04
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 4 TO POINT SOURCE 1 = 0.0

DISTANCE IN METERS FROM GAUGE 1 TO AREA SOURCE 1 = 0.100E 04
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 1 TO AREA SOURCE 1 = 0.270E 03

DISTANCE IN METERS FROM GAUGE 1 TO AREA SOURCE 2 = 0.186E 05
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 1 TO AREA SOURCE 2 = 0.357E 03

DISTANCE IN METERS FROM GAUGE 2 TO AREA SOURCE 1 = 0.100E 04
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 2 TO AREA SOURCE 1 = 0.180E 03

DISTANCE IN METERS FROM GAUGE 2 TO AREA SOURCE 2 = 0.176E 05
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 2 TO AREA SOURCE 2 = 0.0

DISTANCE IN METERS FROM GAUGE 3 TO AREA SOURCE 1 = 0.999E 03 100
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 3 TO AREA SOURCE 1 = 0.900E 02

DISTANCE IN METERS FROM GAUGE 3 TO AREA SOURCE 2 = 0.186E 05
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 3 TO AREA SOURCE 2 = 0.308E 01

DISTANCE IN METERS FROM GAUGE 4 TO AREA SOURCE 1 = 0.100E 04
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 4 TO AREA SOURCE 1 = 0.0

DISTANCE IN METERS FROM GAUGE 4 TO AREA SOURCE 2 = 0.196E 05
DIRECTION IN DEG. CW FROM NORTH FROM GAUGE 4 TO AREA SOURCE 2 = 0.0

ANGULAR SPREAD(LESS THAN 2 RADIANS) FROM GAUGE 1 TO AREA 1 = 0.571E 00
R1= 0.999E 03 R2= 0.101E 04

ANGULAR SPREAD(LESS THAN 2 RADIANS) FROM GAUGE 1 TO AREA 2 = 0.138E-01
R1= 0.186E 05 R2= 0.186E 05

ANGULAR SPREAD(LESS THAN 2 RADIANS) FROM GAUGE 2 TO AREA 1 = 0.573E 00
R1= 0.995E 03 R2= 0.101E 04

ANGULAR SPREAD(LESS THAN 2 RADIANS) FROM GAUGE 2 TO AREA 2 = 0.146E-01
R1= 0.175E 05 R2= 0.176E 05

ANGULAR SPREAD(LESS THAN 2 RADIANS) FROM GAUGE 3 TO AREA 1 = 0.574E 00
R1= 0.994E 03 R2= 0.100E 04

ANGULAR SPREAD(LESS THAN 2 RADIANS) FROM GAUGE 3 TO AREA 2 = 0.138E-01
R1= 0.186E 05 R2= 0.186E 05

ANGULAR SPREAD(LESS THAN 2 RADIANS) FROM GAUGE 4 TO AREA 1 = 0.572E 00
R1= 0.997E 03 R2= 0.101E 04

ANGULAR SPREAD(LESS THAN 2 RADIANS) FROM GAUGE 4 TO AREA 2 = 0.131E-01
R1= 0.196E 05 R2= 0.196E 05

SECTOR FRACTIONS FOR AREA SOURCES

SECTOR FRACTIONS FOR GAUGE 1 AND AREA SOURCE 1

FRACTION FOR SECTOR 1 = 0.0
FRACTION FOR SECTOR 2 = 0.0
FRACTION FOR SECTOR 3 = 0.0
FRACTION FOR SECTOR 4 = 0.0
FRACTION FOR SECTOR 5 = 0.0
FRACTION FOR SECTOR 6 = 0.0
FRACTION FOR SECTOR 7 = 0.0
FRACTION FOR SECTOR 8 = 0.0
FRACTION FOR SECTOR 9 = 0.0
FRACTION FOR SECTOR 10 = 0.0
FRACTION FOR SECTOR 11 = 0.0
FRACTION FOR SECTOR 12 = 0.0
FRACTION FOR SECTOR 13 = 0.02537
FRACTION FOR SECTOR 14 = 0.0
FRACTION FOR SECTOR 15 = 0.0
FRACTION FOR SECTOR 16 = 0.0

SECTOR FRACTIONS FOR GAUGE 1 AND AREA SOURCE 2

```
FRACTION FOR SECTOR  1 =   0.00061
FRACTION FOR SECTOR  2 =   0.0
FRACTION FOR SECTOR  3 =   0.0
FRACTION FOR SECTOR  4 =   0.0
FRACTION FOR SECTOR  5 =   0.0
FRACTION FOR SECTOR  6 =   0.0
FRACTION FOR SECTOR  7 =   0.0
FRACTION FOR SECTOR  8 =   0.0
FRACTION FOR SECTOR  9 =   0.0
FRACTION FOR SECTOR 10 =   0.0
FRACTION FOR SECTOR 11 =   0.0
FRACTION FOR SECTOR 12 =   0.0
FRACTION FOR SECTOR 13 =   0.0
FRACTION FOR SECTOR 14 =   0.0
FRACTION FOR SECTOR 15 =   0.0
FRACTION FOR SECTOR 16 =   0.0
```

SECTOR FRACTIONS FOR GAUGE 2 AND AREA SOURCE 1

```
FRACTION FOR SECTOR  1 =   0.0
FRACTION FOR SECTOR  2 =   0.0
FRACTION FOR SECTOR  3 =   0.0
FRACTION FOR SECTOR  4 =   0.0
FRACTION FOR SECTOR  5 =   0.0
FRACTION FOR SECTOR  6 =   0.0
FRACTION FOR SECTOR  7 =   0.0
FRACTION FOR SECTOR  8 =   0.0
FRACTION FOR SECTOR  9 =   0.02546
FRACTION FOR SECTOR 10 =   0.0
FRACTION FOR SECTOR 11 =   0.0
FRACTION FOR SECTOR 12 =   0.0
FRACTION FOR SECTOR 13 =   0.0
FRACTION FOR SECTOR 14 =   0.0
FRACTION FOR SECTOR 15 =   0.0
FRACTION FOR SECTOR 16 =   0.0
```

SECTOR FRACTIONS FOR GAUGE 2 AND AREA SOURCE 2

```
FRACTION FOR SECTOR  1 =   0.00065
FRACTION FOR SECTOR  2 =   0.0
FRACTION FOR SECTOR  3 =   0.0
FRACTION FOR SECTOR  4 =   0.0
FRACTION FOR SECTOR  5 =   0.0
FRACTION FOR SECTOR  6 =   0.0
FRACTION FOR SECTOR  7 =   0.0
FRACTION FOR SECTOR  8 =   0.0
FRACTION FOR SECTOR  9 =   0.0
FRACTION FOR SECTOR 10 =   0.0
FRACTION FOR SECTOR 11 =   0.0
FRACTION FOR SECTOR 12 =   0.0
FRACTION FOR SECTOR 13 =   0.0
FRACTION FOR SECTOR 14 =   0.0
FRACTION FOR SECTOR 15 =   0.0
FRACTION FOR SECTOR 16 =   0.0
```

SECTOR FRACTIONS FOR GAUGE 3 AND AREA SOURCE 1

```
FRACTION FOR SECTOR  1 =  0.0
FRACTION FOR SECTOR  2 =  0.0
FRACTION FOR SECTOR  3 =  0.0
FRACTION FOR SECTOR  4 =  0.0
FRACTION FOR SECTOR  5 =  0.02549
FRACTION FOR SECTOR  6 =  0.0
FRACTION FOR SECTOR  7 =  0.0
FRACTION FOR SECTOR  8 =  0.0
FRACTION FOR SECTOR  9 =  0.0
FRACTION FOR SECTOR 10 =  0.0
FRACTION FOR SECTOR 11 =  0.0
FRACTION FOR SECTOR 12 =  0.0
FRACTION FOR SECTOR 13 =  0.0
FRACTION FOR SECTOR 14 =  0.0
FRACTION FOR SECTOR 15 =  0.0
FRACTION FOR SECTOR 16 =  0.0
```

SECTOR FRACTIONS FOR GAUGE 3 AND AREA SOURCE 2

```
FRACTION FOR SECTOR  1 =  0.00061
FRACTION FOR SECTOR  2 =  0.0
FRACTION FOR SECTOR  3 =  0.0
FRACTION FOR SECTOR  4 =  0.0
FRACTION FOR SECTOR  5 =  0.0
FRACTION FOR SECTOR  6 =  0.0
FRACTION FOR SECTOR  7 =  0.0
FRACTION FOR SECTOR  8 =  0.0
FRACTION FOR SECTOR  9 =  0.0
FRACTION FOR SECTOR 10 =  0.0
FRACTION FOR SECTOR 11 =  0.0
FRACTION FOR SECTOR 12 =  0.0
FRACTION FOR SECTOR 13 =  0.0
FRACTION FOR SECTOR 14 =  0.0
FRACTION FOR SECTOR 15 =  0.0
FRACTION FOR SECTOR 16 =  0.0
```

SECTOR FRACTIONS FOR GAUGE 4 AND AREA SOURCE 1

```
FRACTION FOR SECTOR  1 =  0.02541
FRACTION FOR SECTOR  2 =  0.0
FRACTION FOR SECTOR  3 =  0.0
FRACTION FOR SECTOR  4 =  0.0
FRACTION FOR SECTOR  5 =  0.0
FRACTION FOR SECTOR  6 =  0.0
FRACTION FOR SECTOR  7 =  0.0
FRACTION FOR SECTOR  8 =  0.0
FRACTION FOR SECTOR  9 =  0.0
FRACTION FOR SECTOR 10 =  0.0
FRACTION FOR SECTOR 11 =  0.0
FRACTION FOR SECTOR 12 =  0.0
FRACTION FOR SECTOR 13 =  0.0
FRACTION FOR SECTOR 14 =  0.0
FRACTION FOR SECTOR 15 =  0.0
FRACTION FOR SECTOR 16 =  0.0
```

SECTOR FRACTIONS FOR GAUGE 4 AND AREA SOURCE 2

FRACTION FOR SECTOR 1 = 0.00058
FRACTION FOR SECTOR 2 = 0.0
FRACTION FOR SECTOR 3 = 0.0
FRACTION FOR SECTOR 4 = 0.0
FRACTION FOR SECTOR 5 = 0.0
FRACTION FOR SECTOR 6 = 0.0
FRACTION FOR SECTOR 7 = 0.0
FRACTION FOR SECTOR 8 = 0.0
FRACTION FOR SECTOR 9 = 0.0
FRACTION FOR SECTOR 10 = 0.0
FRACTION FOR SECTOR 11 = 0.0
FRACTION FOR SECTOR 12 = 0.0
FRACTION FOR SECTOR 13 = 0.0
FRACTION FOR SECTOR 14 = 0.0
FRACTION FOR SECTOR 15 = 0.0
FRACTION FOR SECTOR 16 = 0.0

WIND SPEEDS (M/S) AT HEIGHT OF 10. M

0.90 2.57 4.37 6.94 9.77 12.35

STACK CONDITIONS

SOURCE	NAME	HEIGHT(M)	AMB TEMP(K)	ST TEMP(K)	RADIUS(M)	EXIT VEL(M/S)
POINT 1	POINT 1	80.0	280.0	350.0	1.5	10.00

WIND SPEEDS (M/S) AT POINT 1 SOURCE HEIGHT AS A FUNCTION OF STABILITY

1	1.04	2.97	5.05	8.03	11.30	14.29
2	1.04	2.97	5.05	8.03	11.30	14.29
3	1.11	3.16	5.38	8.54	12.03	15.20
4	1.23	3.51	5.97	9.48	13.35	16.87
5	1.86	5.32	9.05	14.37	20.23	25.57
6	2.82	8.07	13.71	21.78	30.66	38.76

GRASS COVER 1.0

AFTERNOON MIXING HEIGHTS(M)= 600.

NOCTURNAL MIXING HEIGHTS(M)= 400.

DATA FOR POLLUTANT 1 (A GAS)
BOUNDARY LAYER THICKNESS= 1.000E-02 METERS
DIFFUSION CONSTANT FOR WASHOUT= 1.000E-05 METER**2/SEC HALF LIFE= 1.000E 12 SECON

POINT SOURCE EMISSIONS FOR PERIODS
1 ANNUAL

EMISSION RATE FROM POINT SOURCE 1 OF POLLUTANT 1 IN GRAMS/SEC
1.0000E 00

AREA SOURCE EMISSIONS FOR PERIODS
1 ANNUAL

EMISSION RATE FROM AREA SOURCE 1 OF POLLUTANT 1 IN GRAMS/M**2/SEC
1.0000E-02

```
LINE SOURCE EMISSIONS FOR PERIODS
  1  ANNUAL

EMISSION RATE FROM LINE SOURCE    1  OF POLLUTANT    1  IN GRAMS/M/SEC
   1.0000E-02


AREA SOURCE   2  =  WINDBLOWN SOURCE    1  AREA 2


INFORMATION FOR WINDBLOWN SOURCE    1

        ITYPE=    1
        DENSITY=  0.1000E 01  G/CM**3
        SALTATION DIAMETER=  0.1000E-02  METERS
        SUSPENSION DIAMETER=  0.1000E-02  METERS

        CONCENTRATION FACTOR FOR WINDBLOWN SOURCE    1

        POLLUTANT     1      5.0000E-01

        FRACTION OF TIME SOURCE REMAINS DRY DURING
        SEASON    1  =    0.75000

        SUSPENSION TO SALTATION RATIOS FOR SOURCE    1  =  0.1000E 00  1/METER

        DEPOSITION VELOCITY FOR WINDBLOWN SOURCE    1  =  0.2980E 02  METERS/SEC

        EMISSION DATA FROM WINDBLOWN SOURCE    1

        POLLUTANT    1  WIND    1  SOURCE STRENGTH=  0.0          GM/M**2/SEC
        POLLUTANT    1  WIND    2  SOURCE STRENGTH=  0.0          GM/M**2/SEC
        POLLUTANT    1  WIND    3  SOURCE STRENGTH=  0.1639E-01   GM/M**2/SEC
        POLLUTANT    1  WIND    4  SOURCE STRENGTH=  0.6050E 00   GM/M**2/SEC
        POLLUTANT    1  WIND    5  SOURCE STRENGTH=  0.3358E 01   GM/M**2/SEC
        POLLUTANT    1  WIND    6  SOURCE STRENGTH=  0.9149E 01   GM/M**2/SEC

POLLUTANT   1,            POINT SOURCE DEPOSITION RATE (GM/M**2/SEC)

GAGE  POL  ANNUAL
  1    1 3.708E-10
  2    1 2.032E-10
  3    1 2.710E-10
  4    1 4.548E-10
                          POINT SOURCE INCREMENT TO CONCENTRATION (G/M**3)
  1    1 3.535E-09
  2    1 1.263E-09
  3    1 1.644E-09
  4    1 4.341E-09
```

```
POLLUTANT  1,             AREA SOURCE DEPOSITION RATE (GM/M**2/SEC)
  1      1 1.401E-08
  2      1 8.443E-09
  3      1 1.238E-08
  4      1 1.734E-08
                          AREA SOURCE INCREMENT TO CONCENTRATION (G/M**3)
  1      1 1.470E-06
  2      1 8.889E-07
  3      1 1.306E-06
  4      1 1.818E-06

LINE LENGTH=      100.0 M

POLLUTANT  1,             LINE SOURCE DEPOSITION RATE (GM/M**2/SEC)
  1      1 1.400E-08
  2      1 8.441E-09
  3      1 1.236E-08
  4      1 1.742E-08
                          LINE SOURCE INCREMENT TO CONCENTRATION (G/M**3)
  1      1 1.468E-06
  2      1 8.887E-07
  3      1 1.304E-06
  4      1 1.827E-06

     TEST RUN WITH POINT,AREA AND LINE SOURCES

POLLUTANT  1,
```

GAGE	POL	PERIOD	DRYDEP G/M**2/SEC	WETDEP G/M**2/SEC	TOTAL DEP G/M**2/SEC	CONC G/M**3
1	1	1 ANNUAL	2.735E-08	1.024E-09	2.838E-08	2.941E-06
2	1	1 ANNUAL	1.654E-08	5.431E-10	1.709E-08	1.779E-06
3	1	1 ANNUAL	2.429E-08	7.228E-10	2.501E-08	2.612E-06
4	1	1 ANNUAL	3.394E-08	1.274E-09	3.521E-08	3.649E-06

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